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The photograph on the cover was taken by Republic Steel Corporation, Central Alloy District, and represents some interesting objects made from Enduro stainless steel.

Ernest E. Thum, Editor.

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AMERICAN SOCIETY for METALS

THE TIMKEN STEEL AND TUBE CO.
CANTON, OHIO

SUPERIOR QUALITY ELECTRIC FURNACE AND OPEN HEARTH ALLOY STEELS

TIMKEN CHROMIUM MOLYBDENUM STEELS

S. A. E. Steel No.	Carbon Range	Manganese Range	Phos. Max.	Sul. Max.	Chromium Range	Molybdenum Range
4130	.25—.35	.50—.80	.04	.05	.50—.80	.15—.25
4140	.35—.45	.50—.80	.04	.05	.80—1.10	.15—.25
4150	.45—.55	.50—.60	.04	.05	.80—1.10	.15—.25
.....	.30—.40	.40—.60	.04	.05	.80—1.10	.30—.40
.....	.35—.45	.40—.70	.04	.05	.80—1.10	.15—.25
.....	.....	.....	...	...	.....	.....

TIMKEN NICKEL MOLYBDENUM STEELS

S. A. E. Steel No.	Carbon Range	Manganese Range	Phos. Max.	Sul. Max.	Nickel Range	Molybdenum Range
4615	.10—.20	.30—.60	.04	.05	1.50—2.00	.20—.30
4620*	.17—.22	.40—.70	.03	.04	1.50—2.00	.20—.30
4640*	.35—.45	.50—.80	.03	.04	1.50—2.00	.20—.30
23420*	.17—.22	.30—.60	.03	.04	3.25—3.75	.20—.30

*Not officially an S. A. E. Number.

TIMKEN CHROMIUM STEELS

S. A. E. Steel No.	Carbon Range	Manganese Range	Phos. Max.	Sul. Max.	Chromium Range
5120	.15—.25	.30—.60	.04	.05	.60—.90
5140	.35—.45	.50—.80	.04	.05	.80—1.10
5150	.45—.55	.50—.80	.04	.05	.80—1.10
52100	.95—1.10	.20—.50	.03	.035	1.20—1.50

TIMKEN NICKEL STEELS

S. A. E. Steel No.	Carbon Range	Manganese Range	Phos. Max.	Sul. Max.	Silicon	Nickel Range
2015	.10—.20	.30—.60	.04	.05	.15—.30	.40—.60
2115	.10—.20	.30—.60	.04	.05	.15—.30	1.25—1.75
2315	.10—.20	.30—.60	.04	.05	.....	3.25—3.75
2320	.15—.25	.30—.60	.04	.05	.....	3.25—3.75
2330	.25—.35	.50—.80	.04	.05	.....	3.25—3.75
2335	.30—.40	.50—.80	.04	.05	.....	3.25—3.75
2340	.35—.45	.50—.80	.04	.05	.....	3.25—3.75
2345	.40—.50	.50—.80	.04	.05	.....	3.25—3.75
2350	.45—.55	.50—.80	.04	.05	.....	3.25—3.75
2512	Max. 0.17	.30—.60	.04	.05	.....	4.75—5.25

TIMKEN CHROMIUM-VANADIUM STEELS

S. A. E. Steel No.	Carbon Range	Manganese Range	Phos. Max.	Sul. Max.	Chromium Range	Vanadium Min.	Vanadium Desired
6115	.10—.20	.30—.60	.04	.045	.80—1.10	.15	.18
6120	.15—.25	.30—.60	.04	.045	.80—1.10	.15	.18
6125	.20—.30	.50—.80	.04	.045	.80—1.10	.15	.18
6130	.25—.35	.50—.80	.04	.045	.80—1.10	.15	.18
6135	.30—.40	.50—.80	.04	.045	.80—1.10	.15	.18
6140	.35—.45	.50—.80	.04	.045	.80—1.10	.15	.18
6145	.40—.50	.50—.80	.04	.045	.80—1.10	.15	.18
6150	.45—.55	.50—.80	.04	.045	.80—1.10	.15	.18
6195	.90—1.05	.20—.45	.03	.035	.80—1.10	.15	.18

TIMKEN NICKEL-CHROMIUM STEELS

S. A. E. Steel No.	Carbon Range	Manganese Range	Phos. Max.	Sul. Max.	Nickel Range	Chromium Range
3115	.10—.20	.30—.60	.04	.05	1.00—1.50	.45—.75
3120	.15—.25	.30—.60	.04	.05	1.00—1.50	.45—.75
3125	.20—.30	.50—.80	.04	.05	1.00—1.50	.45—.75
3130	.25—.35	.50—.80	.04	.05	1.00—1.50	.45—.75
3135	.30—.40	.50—.80	.04	.05	1.00—1.50	.45—.75
3140	.35—.45	.50—.80	.04	.05	1.00—1.50	.45—.75
3145	.40—.50	.50—.80	.04	.05	1.00—1.50	.45—.75
3150	.45—.55	.50—.80	.04	.05	1.00—1.50	.45—.75
3215	.10—.20	.30—.60	.04	.045	1.50—2.00	.90—1.25
3220	.15—.25	.30—.60	.04	.045	1.50—2.00	.90—1.25
3230	.25—.35	.30—.60	.04	.045	1.50—2.00	.90—1.25
3240	.35—.45	.30—.60	.04	.045	1.50—2.00	.90—1.25
3245	.40—.50	.30—.60	.04	.045	1.50—2.00	.90—1.25
3250	.45—.55	.30—.60	.04	.045	1.50—2.00	.90—1.25
3312	Max. .17	.30—.60	.04	.045	3.25—3.75	1.25—1.75
3325	.20—.30	.30—.60	.04	.045	3.25—3.75	1.25—1.75
3335	.30—.40	.30—.60	.04	.045	3.25—3.75	1.25—1.75
3340	.35—.45	.30—.60	.04	.045	3.25—3.75	1.25—1.75
3415	.10—.20	.30—.60	.04	.045	2.75—3.25	.60—.95
3435	.30—.40	.30—.60	.04	.045	2.75—3.25	.60—.95
3450	.45—.55	.30—.60	.04	.045	2.75—3.25	.60—.95

TUNGSTEN STEELS

S. A. E. Steel No.	Carbon Range	Manganese Max.	Phos. Max.	Sul. Max.	Chromium Range	Tungsten Range
71360	.50—.70	.30	.035	.04	3.00—4.00	12.00—15.00
71660	.50—.70	.30	.035	.04	3.00—4.00	15.00—18.00
7260	.50—.70	.30	.035	.04	.50—1.00	1.50—2.00

CARBON STEELS

S. A. E. Steel No.	Carbon Range	Manganese Range	Phos. Max.	Sul. Max.
1010	.05—.15	.30—.60	.045	.055
1015	.10—.20	.30—.60	.045	.055
1020	.15—.25	.30—.60	.045	.055
1025	.20—.30	.50—.80	.045	.055
1030	.25—.35	.50—.80	.045	.055
1035	.30—.40	.50—.80	.045	.055
1040	.35—.45	.50—.80	.045	.055
1045	.40—.50	.50—.80	.045	.055
1050	.45—.55	.50—.80	.045	.055
1095	.90—1.05	.25—.50	.040	.050
1315	.10—.20	1.25—1.55	.050	0.080—0.130
1350*	.45—.55	.90—1.20	.040	.050
1360*	.55—.70	.90—1.20	.040	.050

*Silicon content for 1350 and 1360 shall not exceed 0.30 per cent.

TIMKEN SILICO-MANGANESE STEELS

S. A. E. Steel No.	Carbon Range	Manganese Range	Phos. Max.	Sul. Max.	Silicon Range
9250	.45—.55	.60—.90	.045	.05	1.80—2.20
9260	.55—.65	.60—.90	.045	.05	1.80—2.20

Silicon range of all S. A. E. basic open hearth alloy steels shall be 0.15—0.30. For electric and acid open hearth steels the silicon content shall be a minimum of 0.15.

TIMKEN HIGH MANGANESE STEELS

Carbon	Mn.	P.	S.	Si.
.12—.18	1.80—2.10	.04	.05	.15—.30
.25—.35	1.60—1.90	.04	.05	.15—.30
.35—.45	1.60—1.90	.04	.05	.15—.30

SPECIAL TIMKEN STEELS

	C	Mn.	P	S	Si.	Ni.	Cr.	Mo.	V
Cr. Ni. Mo.	.35—.45	.30—.60	.03	.03	.15—.30	1.50—2.00	.45—.75	.30—.40	.....
Krupp	.08—.16	.30—.60	.03	.03	.15—.30	3.75—4.25	1.25—1.75	.....	.....
Ni. Cr. V.	.10—.20	.30—.60	.04	.04	.15—.30	.40—.60	.45—.75	.....	.15—.20

TIMKEN HIGH TEMPERATURE AND CORROSION RESISTING STEELS

	C	Mn.	P	S.	Si.	Cr.	Mo.	W.	V.
"17-22"	.40—.50	.30—.60	.03	.03	.50—1.00	1.10—1.40	.45—.65	.80—1.10	.25—.35
C. Mo.	.10—.20	.30—.60	.04	.045	.25 Max		.25—.35		
Q. V.	.15Max	1.85—2.15	.03	.03	.15—.30	1.00—1.50	.40—.60		.18—.25
DM-45	.40—.50	.40—.70	.03	.03	.50—.90				

	C.	Mn.	P.	S.	Si.	Cr.	Mo.	W.
DM	.15Max	.30—.60	.03	.03	.50—1.00	1.00—1.50	.40—.60	.....
MM-9	.15Max	1.10—1.40	.03	.03	.15—.30	.....	.20—.30	.....
5% Cr.	.15Max	.50Max	.03	.03	.50Max	4.00—6.00	.....	.....
5% Cr. Mo.	.15Max	.50Max	.03	.03	.50Max	4.00—6.00	.45—.65	.....
5% Cr. W.	.15Max	.50Max	.03	.03	.50Max	4.00—6.00	.....	.75—1.25

ALSO ALL STAINLESS STEELS FOR VARIOUS USES

AND OTHER SPECIAL INTERMEDIATE ALLOY STEELS FOR RESISTING CREEP AND CORROSION

Revised March, 1934

Printed in U.S.A.

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All these Steels are made by TIMKEN

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Timken Alloy Steels—manufactured under Timken quality control—are noted for their uniform chemical and physical characteristics; uniformly-controlled grain size; correct metallographic structure; and satisfactory response to heat treatment. They offer you a definite opportunity to make appreciable savings in production costs, for Timken pioneering in alloy steel development has resulted in steels that are setting new standards of performance wherever they are used.

Timken metallurgists will be glad to cooperate in the selection of the most suitable steel for any type of service.

THE TIMKEN STEEL AND TUBE COMPANY, CANTON, OHIO

TIMKEN ALLOY STEELS
ELECTRIC FURNACE AND OPEN HEARTH
ALL STANDARD AND SPECIAL ANALYSIS

Write for 8½ x 11" size copy of this handy up-to-date specification sheet.

BEARING steel must be clean steel, and by clean we mean just about the closest approach to the absolute in cleanliness that has been attained in steel-making. This is so important because, in steel of the extreme hardness used in bearings, the most minute inclusion may form the nucleus of a fracture.

Cleanliness is, of course, fundamental and taken for granted in making all alloy steels. But in making bearing steels Bethlehem enforces a standard of cleanliness as far ahead of the usual standards of good practice as the surgeon's standard of cleanliness is ahead of the layman's.

In addition to cleanliness, Bethlehem Bearing Steels have machinability that keeps production costs low, uniform heat-treating characteristics that simplify control of the hardening operations, and controlled grain-size that assures the maximum physical properties that the analysis is capable of developing.

No wonder Bethlehem's output of bearing steel is steadily increasing.

BETHLEHEM STEEL *BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.*

BETHLEHEM *Fine* ALLOY STEELS

Low Carbon 18-8 Castings by Sivyer Steel Casting Co.

Metal Beauties

By John A. Mathews
Vice-President
Crucible Steel Co. of America
New York

COLUMBIUM

to stabilize 18-8 steel

EDITOR'S NOTE: Dr. Mathews has forwarded this material as a supplement to his chapter on "Alloy Modifications of 18-8" in the second edition of The Book of Stainless Steels. His findings give independent verification of the utility of this alloying addition, based, as they are, on studies of 8-ton heats made under commercial conditions rather than on experimental melts.

THE latest addition to the 18% chromium, 8% nickel steel is columbium. This improvement was described by F. M. Becket and Russell Franks of Union Carbide & Carbon Research Laboratories before the February meeting of the American Institute of Mining & Metallurgical Engineers.

The specific advantage of columbium is in retarding susceptibility to intergranular corrosion, particularly after long holding at temperatures from 1000 to 1500° F., when the use of the alloy requires operation within that range.

The commercial use of columbium in ferrous metallurgy is quite new. The receipt for making rabbit pie begins, "First catch your rabbit"; Dr. Becket and his associates had to search for columbium-containing minerals and, having found them, develop a process for converting them into ferrocolumbium.

It is well known that considerable difficulty has been experienced with the deterioration of commercial 18-8 steels, especially alongside the welded joints, when subjected to heat and severely corroding fluids. Two manifestations of this change are intergranular attack by corrosives and reduced impact values. (It is frequently overlooked, however, that the soaking temperature which produces maximum susceptibility to intergranular attack is not the same temperature at which minimum resistance to impact occurs upon reheating the 18-8 steel or its modifications; the temperature for lowest impact resistance is usually about 200° F. higher.) The columbium addition is stated by Becket and Franks to improve both of these potential weaknesses in the 18-8 steel.

The columbium modification shows very great resistance to intergranular susceptibility after reheating for long periods between 600 and 1600° F. when tested by the copper-sulphate sulphuric acid method (boiling in 6% copper sulphate solution containing 10% sulphuric acid). The presence of approximately four times as much columbium as carbon diminishes the range of temperature through which the austenitic steels are made susceptible to grain boundary attack, and when the ratio of columbium to carbon is increased to about seven to one, a marked improvement is obtained — although it may still be possible to disintegrate the steel by hot copper sulphate in sulphuric acid. A columbium ratio of ten times the carbon yielded steels that failed to disintegrate in that solution after either a long or a short stay between 600 and 1500° F.

When the carbon is very low, columbium tends to correct the loss of toughness resulting from exposure in the range of 1200 to 1500° F.

The columbium addition has relatively little effect on the general static properties in the annealed condition. (It is to be noted in Becket and Franks' paper that their annealing temperature was unusually high, namely, 2100° F. It is generally recognized that annealing from excessively high temperatures is more deleterious to the steel when reheated in the embrittling zone than when the annealing is performed at lower temperature, such as 1900° F., or when the material is given a stabilizing anneal at from 1550 to 1650° F.)

Reheating the austenitic 18-8 steel and its modifications from 1000 to 1400° F. usually results in a lowering of general over-all corrosion resistance, but this over-all corrosion may or may not be accompanied by a tendency to intergranular attack, depending upon the electrolyte. When tested in hot 65% nitric acid, the two effects are additive, while if samples are tested with copper sulphate and sulphuric acid, there is no general attack but an intergranular corrosion only. It is because of the very highly selective nature of the latter test that we prefer it to any other, because it shows up the one thing in which we are interested, namely, intergranular susceptibility.

To illustrate: Tests were made of a columbium-bearing heat of 0.07% carbon, 9.0% nickel, 17.6% chromium and 0.31% columbium. In this steel the columbium to carbon ratio is a little better than four to one. Samples were given either a stabilizing anneal at 1600° F. for 6 hr. or a quench after a stay at 1900° F. The material was then subjected to boiling 65% nitric acid, following reheating temperatures of 1100, 1200 and 1300° F. These reheating temperatures were continued for two different periods, namely, 10 min. and 16 hr.

For the shorter reheating period there was practically no increase in the nitric acid attack as compared with the simple annealed material not reheated to the dangerous range. But when the reheating was continued for 16 hr. there was an increase in nitric acid attack, particularly after the 1100 and 1200° F. treatments, both in the stabilized condition and in the 1900° F. annealed condition. However, the increased losses following specific heating conditions with the columbium steel were a very small fraction of the losses obtained on a KA-2 S (low carbon 18-8) steel of the same composition but without columbium, and similarly treated.

Although the nitric acid resistance was decreased by long reheating, it was found that none of the columbium-bearing samples showed intergranular attack in boiling acid copper sulphate solution after 220 hr. In this case, therefore, even a four to one columbium ratio has proven very effective in preventing intergranular susceptibility. It has also proven very helpful in cutting down over-all corrosion as compared with plain KA-2 S, even though there was noted some increase in the attack by nitric acid after

Twenty-Ton Fractionating Tower (6½ × 59½ Ft.) Being Welded of ⅜-In. Plates of 18-8 Stainless Steel. Photo courtesy Lincoln Electric Co.

Beauty of Architectural Line Accentuated by Stainless Steel Sheet and Bars. Photo courtesy Crucible Steel Co. of America

holding the sample 16 hr. at 1100 and 1200° F.

It is too early to predict what ultimate use-value the columbium addition will have, but it seems quite probable that for welded construction intended for service in the embrittling zone of temperatures it may find a useful application. Welding rod to be used on such construction should preferably have a columbium content not less than ten times the carbon. After making the weld the columbium remaining in the deposited metal will then still be sufficiently high to insure resistance to intergranular attack after reheating. Columbium is fairly readily oxidized, but the loss in welding will not be nearly so great as the loss of titanium in the rod containing the latter element. Our experience is that practically all of the titanium is lost during deposition; this will not be the case with columbium steels, although there will be an appreciable decrease in the columbium remaining in the weld metal.

By H. W. McQuaid
Republic Steel Corp.
Detroit

GAS CARBURIZING

a discussion of shop practices

GAS carburizing is, when properly conducted, one of the simplest processes, and can produce a case of any reasonable characteristics as to carbon concentration, depth, and gradation. Unfortunately, many metallurgists have acquired the impression that there is something occult about the operation, and that there is expensive and delicate equipment required. In an attempt to clear away this fog, this discussion of gas carburizing is intended to be as free from theory as possible. In fact, it is hoped that it will not be necessary to use any chemical formulas or mathematics. It is hoped that the practical fundamentals of gas carburizing will be made clear in the simplest form without sacrificing accuracy or introducing misleading analogies.

During the last ten years there have appeared many articles describing supposedly new methods of gas carburizing. Many very excellent investigations have also been published concerning the reactions between the various gases which enter into the case hardening process and their effects on the steel. A number of technical articles concerning gas carburizing begin by describing the antiquity of carburizing and comment on the slow, uneconomical and dirty methods supposedly inseparable to the process of carburizing with solid compounds. It is frequently stated that the latter is essentially the same process as it was a hundred years ago when charcoal and carbonates were mixed into home-made case hardening or cementing materials.

It is usual also to find in most articles an equation showing that two parts of carbon monoxide under certain conditions will form one part of free carbon plus one part of carbon dioxide — and that under other conditions this reaction reverses. This forms a simple explanation of the source of carbon in pack carburizing by which the outside layers of the hot steel obtain an increasing amount of carbon. It is sometimes said that the carbon monoxide gas actually penetrates the metal and then gives up its carbon; any oxygen resulting in the breakdown of the carbon monoxide then must find its way back out to the surface. Just how this could be done was never clear, yet for many years there have been advocates of the gaseous theory of carbon absorption who firmly believe that carbon is actually carried into the steel by a gas.

Whatever the actual mechanism of the process (and more will be said about this later), one of the primary objects of the researches on gas carburizing was to shorten the process (increase the rate of penetration) as compared to the conventional operations with solid compounds. Most of the proposed methods described what were essentially closed retorts containing the work,

in which carburizing gas could be introduced and then by special manipulation, according to the inventors' theory, the special gases or processes would result in greatly shortening the time required. It was recognized on all sides that carbon monoxide of itself was an extremely slow and relatively unreliable carburizer. Just how this poor carburizing gas could act so well in a carburizing box containing solid carburizing compound was hard to understand. Nevertheless, it was not difficult to show that pure carbon monoxide gas is not a commercial carburizer.

Action Speeded by Hydrocarbons

Most of the processes which were intended to improve gas carburizing required, therefore, the addition of one or more hydrocarbon gases to obtain satisfactory results. Since these hydrocarbons were unstable at the carburizing temperature and deposited carbon on the work at a very fast rate, the problem then became one of soot control. It is known that coke deposited on the work from the break-down of liquid hydrocarbons, or soot from hydrocarbon gases, immediately interferes with the ability of the austenite to take up carbon.

This instability of the hydrocarbon gases was in some cases overcome or reduced by changing the temperature or pressure, and in others by diluting with gases such as nitrogen, ammonia, or city gas. In still other processes the soot was permitted to deposit on the work and oxidizing gases were then introduced (such as wet carbon dioxide, or in some cases straight carbon dioxide) to remove this soot by combination. In doing this, one method was to shut off the soot-producing gases for a short time and during this interval to introduce oxidizing gases of some sort.

In appraising the commercial utility of any of these schemes it is well to bear in mind the simple fundamentals. The prime necessity for carburizing of any kind is to have *carbon* available at the surface of the steel in such a condition that it will dissolve in the surface austenite as fast as the inward diffusion of the carbon already in the austenite will permit. Diffusion of carbon in a given steel depends only on time and temperature, and the surface austenite can only dissolve additional carbon as diffusion from the surface inward reduces the carbon concentration at the surface below the equilibrium percentage for the given temperature.

Harry McQuaid writes from long and rich experience with carburizing problems, not only with rollers, cups and cones for roller bearings, but with automobile transmission gears made of various alloy steels. His verdict that gas carburizing is simple if a few fundamental precautions are observed, is therefore authoritative.

It is quite evident, therefore, that it is hopeless to try to speed up the rate of carbon penetration by varying the carburizing medium, and it has been quite well established that diffusion of carbon is independent of the carbon concentration *on* the surface, or the manner in which the carbon is supplied to that surface. Therefore, if we wish to increase the carbon penetration for a given steel we must either increase the temperature or lengthen the time at temperature — or both.

It is important at this time to point out the fact that the time and temperature, at heat, of work packed in solid compounds varies considerably in the conventional commercial practice from the data recorded on the pyrometer chart for the furnace. It has been determined that a given part will carburize at exactly the same rate in solid compound as it will in gas, if the time and temperature conditions are exactly the same. This can be checked by using thin sheet metal containers, with a small amount of compound, and recording carefully the time and temperature *of the work* by an accurate couple.

Thus it has been found quite possible on a commercial basis to obtain a case depth of 0.060 in. in 5 hr. total time at 1700° F. with solid carburizers, which checks very closely the time required at this temperature in a gas carburizing furnace. The insulating effect of most carburizing compounds is very great, and the delay due to this reason generally explains the difference of time between gas carburizing and solid carburizing, although, of course, the fact that the containers themselves must be heated each time is also another important factor.

It should also be evident that the pressure of the gas used for carburizing has little or no relation to the rate of diffusion of solid or atomic carbon in austenite, and therefore the depth of case. Some metallurgists contend that by increasing the pressure in the carburizing container from 8 oz. to 15 lb. per sq.in., the rate of carbon pen-

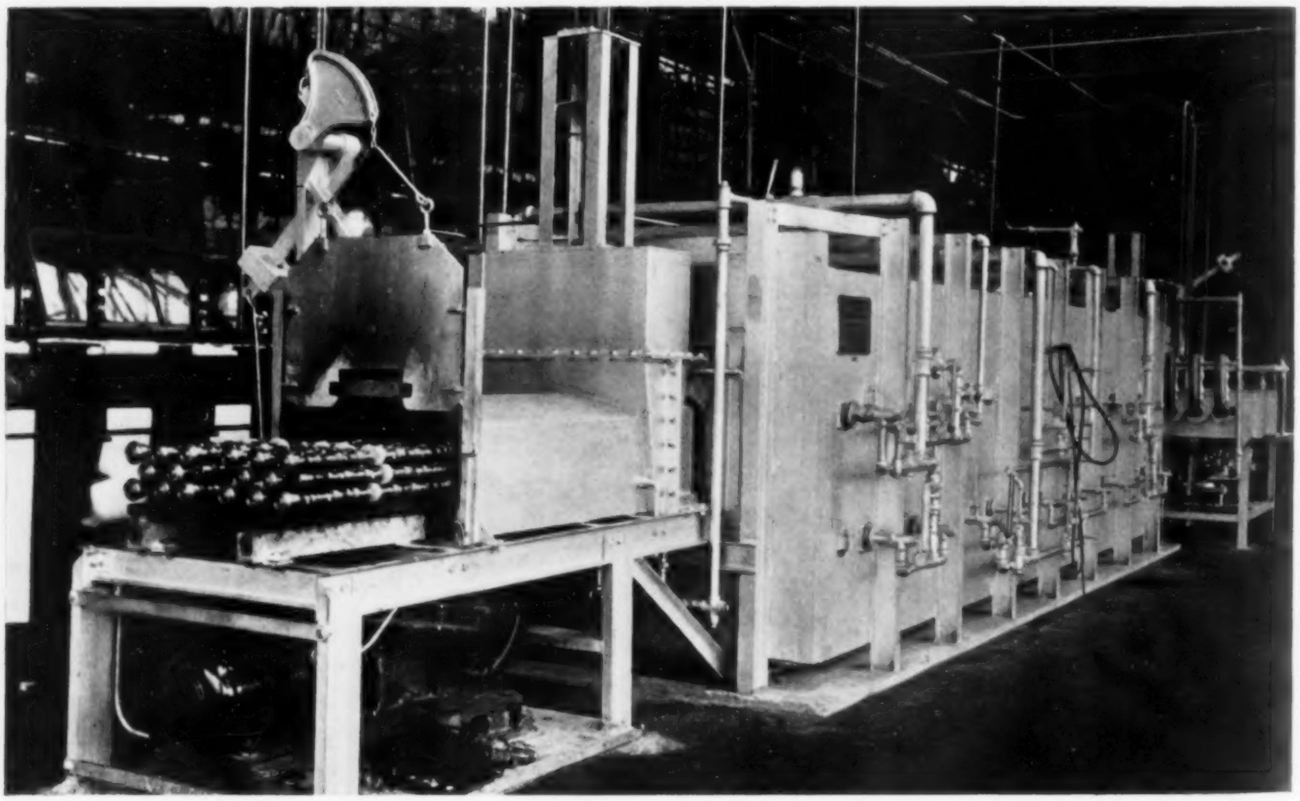
etration was materially increased. There is no doubt that the time in carburizing was shortened, but the improvement was due, not to an increased diffusion rate, but rather to an increased stability of the hydrocarbon gases under the increased pressure.

Temperature Most Important Factor

The most important factor, therefore, in increasing the rate of penetration of carbon is temperature. This means, of course, the temperature of the work itself. Every effort should be made to bring the work up to heat in the shortest possible time. This is difficult to do with large boxes containing an insulating medium such as charcoal carburizing compound. However, considerable improvement can be made by the use of sheet metal containers, by decreasing the amount of carburizing compound between container and work, and in some cases by using specially designed containers which conform to the shape of the individual piece.

The importance of the ratio of carburizing compound to work has been very much magnified. With a container of correct design it has been found that very much less compound is required than has been usually recommended. In one plant carburizing ring gears the time has been decreased, solely by a change in box design, from an average of 17 hr. to 7 hr. for a case of 0.050 to 0.060 in. deep. At the same time, the ratio of compound to work has been decreased to a figure which would be considered impossible in most plants.

Gas carburizing, as we know it, has the particular advantage over a solid carburizing operation in that the work can be brought to heat much more rapidly; carburizing is therefore proceeding at a much higher percentage of the total time the work is in the furnace. However, since temperature alone controls the rate of penetration for a given steel, all we can hope to gain by the study of the gas to be used is a knowledge which will enable us to obtain a case with the desired carbon content at the surface and to eliminate those variables which result in uneven cases and low carbon cases which result in rejected work. Since the operating details are of great importance, it would be well to consider first



Charging End of Continuous Gas Carburizing Furnace, Installed for Olds Motor Co. by Surface Combustion Co. Notice gas lock into which a load of cam shafts is about to enter

what happens when the carburizing gas comes in contact with the hot steel, in the austenitic condition.

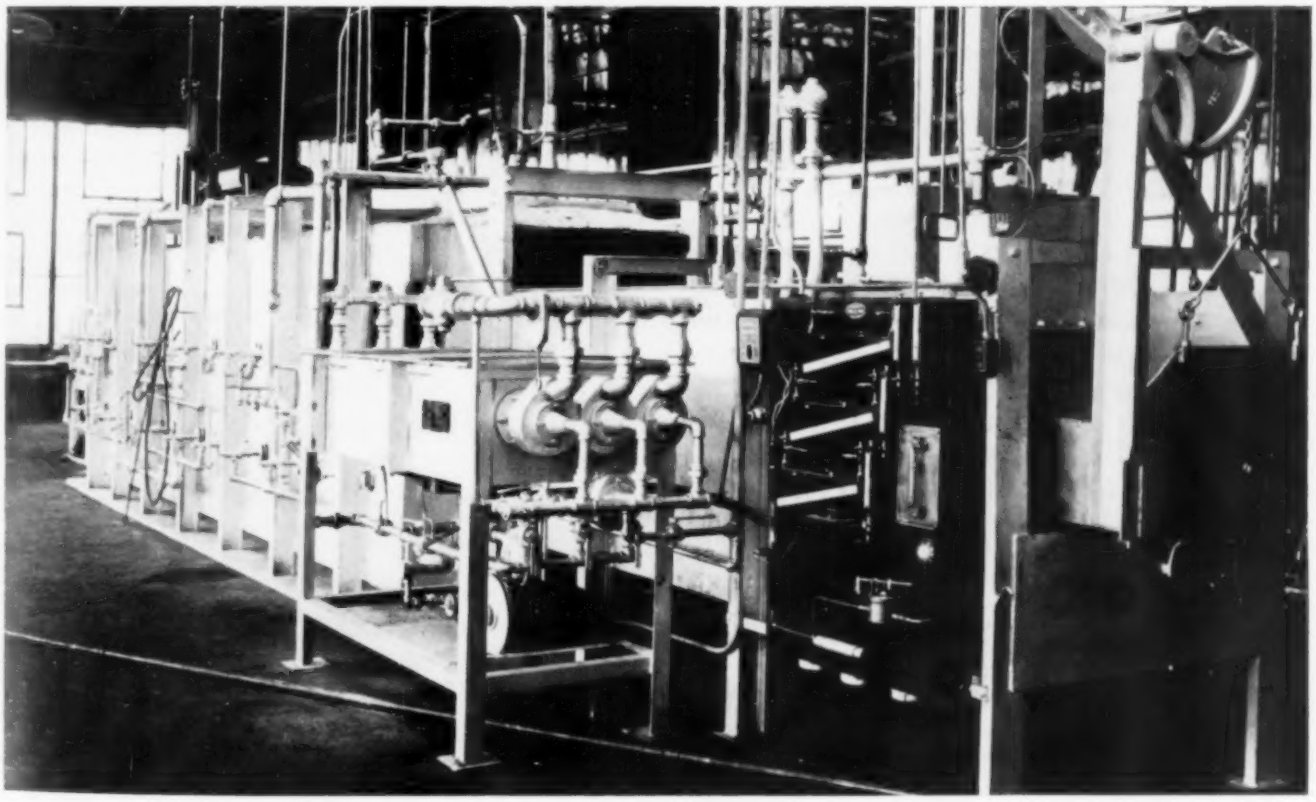
If the gas is nothing but carbon monoxide, there is an immediate tendency to break down to form free carbon and carbon dioxide, which tendency is increased or "catalyzed" by the presence of the austenite. Consequently, carbon monoxide can supply some carbon for solution in the austenite, although the action is relatively very slow as compared with some hydrocarbons. Whether this reaction proceeds at all in pure dry carbon monoxide without circulation is not certain, and unless there is a high percentage of carbon monoxide and some incandescent carbon nearby to reduce the carbon dioxide back to carbon monoxide, we immediately arrive at an equilibrium between austenite, carbon monoxide, and carbon dioxide, and then carburizing stops.

The presence of a small amount of water vapor will tend to slow down the reactions which furnish carbon to the surface of the hot steel, so that solid compounds containing moisture are very poor carburizing agents.

Since carbon monoxide is such a poor source of carbon in the absence of relatively large masses of incandescent carbon, it does not provide a satisfactory agent in gas carburizing. Therefore we must use a gas which supplies carbon at a greater rate to the austenite. We have for this purpose many gases and mixtures ranging from ordinary carburetted water gas to the chemical compounds such as propane or butane, rich in available carbon. The latter gases present the difficulty that they deposit carbon too rapidly so that the work becomes coated with a soot (and in some cases, coke) which interferes with the reaction between the carbonaceous gas and the austenite.

Atomic Carbon Necessary

It is apparently necessary that carbon must have a nascent or atomic form to be dissolved by austenite; it cannot enter into solution if it is in the form of soot or coke. The problem then becomes one of first supplying gas which will, in the presence of austenite, break down to form atomic carbon, but will not in commercial operation build up molecular carbon in the



Discharge End of Same Furnace. Cracking and conditioning triple-unit, together with control panels, for the carburizing gas in central foreground

form of soot to interfere with the contact between the steel and the hydrocarbon gas. Tests have shown that the presence of even a small layer of soot reduces the case depth considerably, so that we must develop some means for controlling the rate of carbon deposit if we are to carburize satisfactorily.

The intermittent surge method of Guthrie, described in Metal Progress, November, 1931, provides one method of overcoming the difficulty. In many applications it has proven commercially successful. In my opinion it introduces some operating complications and does not improve the case obtained as compared with methods using a properly controlled rate of carbon deposition. Likewise Cowan's method of introducing an oxidizing or flue gas with the carburizing gas to remove the soot as fast as it is formed (described in Metal Progress, February, 1932) is extremely difficult to control with such gases as propane or butane, which deposit soot at a rapid rate.

Cowan's method has been quite satisfactory, however, when used with a more stable gas, such as natural gas containing a very high percentage of methane. Even in these circumstances, I am doubtful whether the results obtained are as good as those which would be obtained by reducing the rate of carbon deposition of the methane.

Most of the articles on gas carburizing describe supposed methods of increasing the activity of carbon monoxide gas by adding some hydrocarbon, but what is really happening is that the carbon monoxide (or the lean city gas) is diluting the richer hydrocarbon gases. Due to the dilution of an active hydrocarbon by the relatively inert (to the carburizing operation) carbon monoxide, carbon is deposited on the work at a very much reduced rate and within controllable limits. The rate of deposition of carbon from a given hydrocarbon gas on work in a gas carburizing furnace can be controlled by the addition of a diluting gas such as nitrogen, city gas, or carbon monoxide. This actually controls the rate at which carbon is added to the austenite, permits a very satisfactory commercial operation, and eliminates need for carefully designed control units and constant supervision.

Commercial Considerations

The usual method for establishing the proper proportions is to start off with a lean gas mixture and increase the hydrocarbon content until the most satisfactory case is produced. Proportions can be varied over a considerable range without any noticeable change in the results, so that commercial control is easy. In the usual plant it can be obtained by means of gas meters and valves, because the proportions need not be changed over long periods of time.

It will be found that uniformity, even in a controlled atmosphere which gives satisfactory case characteristics, will not be obtained unless the velocity of the gas in contact with the surface to be carburized is above a certain minimum rate. For this reason it becomes immediately necessary to have sufficient circulation of the gases in the retort, so that every part to be carburized is swept by the carburizing gas. In some cases, where the parts are intricate or circulation is impeded, it will be necessary to increase the rate of flow considerably above the minimum necessary for satisfactory results in more exposed pieces. Stagnation is to be eliminated by all means; turbulence is a very important factor in obtaining uniform results.

Temperature Must Be Constant

The importance of uniform temperature through every piece, if uniform results are to be obtained, has not been stressed, but it is, of course, a very important factor. Many furnaces have failed to produce uniform carburizing results because of different temperature gradients at top and bottom in the pit type furnace, and from one section to another in the retort type. It should be needless to say that most careful attention must be given to the temperature, so it will be maintained within plus or minus 5° F. in every part of the work, if the most uniform results are to be obtained. This is not easy, but is possible. By controlling the stability of the carburizing gas by dilution, and carefully controlling the temperature and time at heat, it is possible to obtain very satisfactory and economical results in a properly designed unit.

Where low carbon cases are particularly required, such as in bearings, it is generally necessary to establish a diffusion period during which the carbon is not being supplied at the surface, but is diffusing into the work from the surface. During this time there is a decrease in the percentage of carbon at the surface with an increase in case depth. In those processes where a simple carburizing gas is used, it is merely necessary to shut off the gas entirely for several hours while maintaining the temperature.

Where a mixed gas is used and carbon is

deposited at a controlled rate, the percentage of carbon in the case can be varied according to the percentage of hydrocarbon gas in the atmosphere. Using this method in the retort batch type of furnace, such as is illustrated below, the diffusion period can also be used, but in the continuous type of furnace, such as shown on pages 24 and 25, the diffusion period is difficult to establish. It then becomes necessary to balance the hydrocarbon gases more accurately with a rate of diffusion. This is not so simple to do, so that the continuous type of furnace might introduce difficulties in the production of low carbon cases. It is, however, ideally suited for the usual higher carbon case; the simplicity of the operation and the minimum of supervision required to obtain uniformly satisfactory work give it a great advantage.

Batch Type of Gas Carburizer (American Gas Furnace Co.) in Operation at Cleveland Tractor Co. Plant

If city gas is used to dilute the hydrocarbon gases, all that is necessary for satisfactory control is two flow meters, one for city gas and the other for the hydrocarbon. If air is used, it has been found advisable to crack the hydrocarbons by preheating the mixture to a temperature approximately the same as in the carburizing retort. Apparently this has been satisfactorily worked out; cracking units such as shown alongside the furnace on page 25 are now available.

A Simple Process

To summarize the whole subject, the statement made at the start may be repeated: Gas carburizing is, when properly conducted, one of the simplest processes and enables us to get cases of any desired characteristic. When properly conducted it is possible to obtain a depth of case, a carbon content, and gradation of carbon within almost any desired limit.

There are two important requirements in gas carburizing, the first and most important of which is uniform temperature. Second is a satisfactory carburizing gas.

Most of the past difficulties have been due to attempts to utilize an unsuitable gas. In an endeavor to utilize a gas which supplies carbon at too low a rate, many delicate operations have been added to the process which render it very sensitive. On the other hand, carburizing gases rich in carbon (and at the same time unstable), introduce difficulties from too heavy a deposit of carbon on the surface of the work. By diluting the rich carbonaceous gas with the weaker gas, it is possible to arrive at a commercial carburizer which is practically foolproof and without the necessity of drying towers, delicate control apparatus, or special supervision.

With the temperature under control and a satisfactory gas mixture, a uniform case at a maximum rate of penetration requires only a correct rate of circulation of the gases over the surface of the work. The minimum rate of circulation can be easily established by actual trial. The proper percentage of hydrocarbon and diluting gas can also be determined by a few trial runs, starting with a minimum of the rich gas.

By a diffusion period, at heat but without gas circulation, a case can be obtained which has any desired carbon content at the surface and practically any rate of gradation from the surface to the core.

By Frank J. Allen
Engineer
York Ice Machinery Corp.
York, Pennsylvania

SELECTING AND BUYING

the right steel for the part

WHAT is the most suitable material for the job? This is the question always confronting the progressive manufacturer. The successful stimulation of sales by changes of style or increase in efficiency depends greatly on the answer to this question. Deriving inspiration from this demand and itself in turn inspiring new things to be made, science answers with the invention of new materials and the improvement and adaptation of existing ones. Perhaps in the field of ferrous metallurgy has the advance been most intense and rapid. The final product may be of steel, and always are steels involved in its making and fabrication.

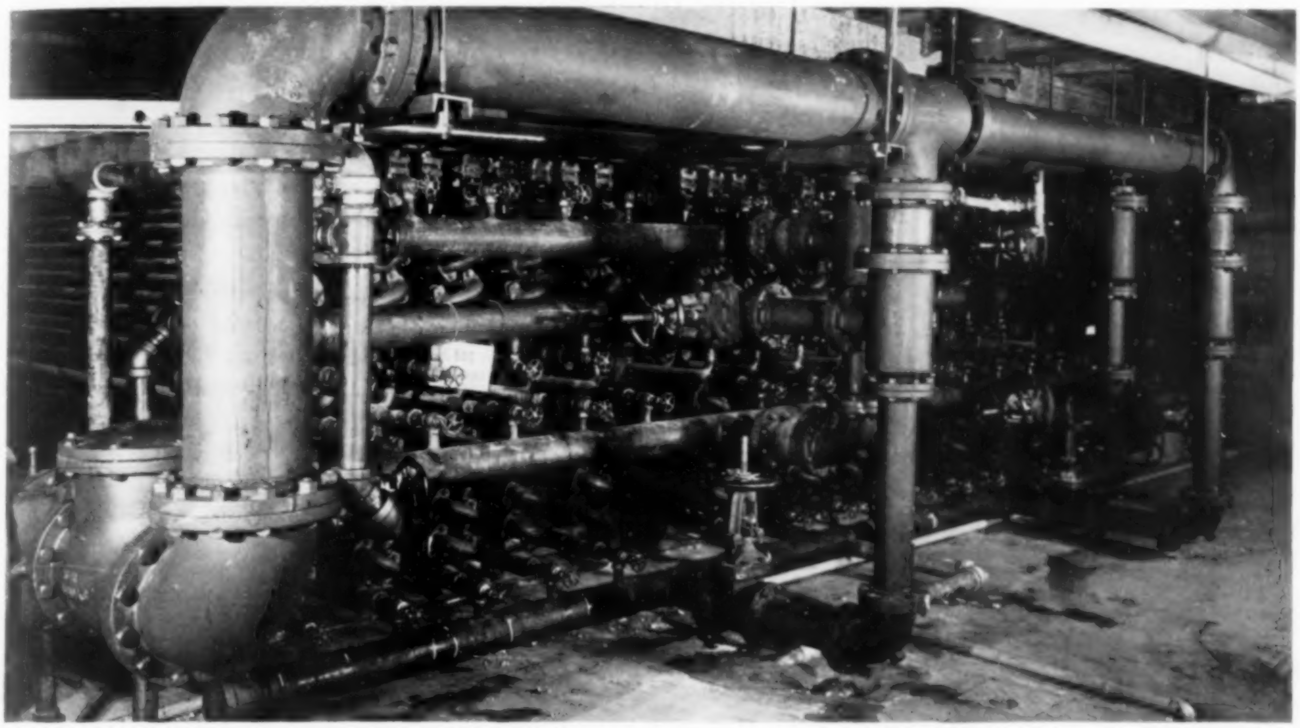
In contrast with the care expended on the other phases of manufacture is the haphazard system so often employed in the selection and purchase of materials. This is often left entirely to the purchasing department which, while skilled in the art of purchasing, is all too frequently lacking technical information about the raw materials bought.

Anticipating that some of our friends in the purchasing departments will question this statement, proof may be found in the membership roster of the American Society for Testing Materials, our leading organization engaged in the preparation of specifications for technical materials. Of the 165 members starting with "A" in the alphabetical classification, only one has a title which indicates that his principal duties are in the purchasing department.

The defense will be that it is asking too much to expect the purchasing department, manned by individuals of non-technical interests and training, to be well-informed about the latest developments in the applications of various steels and other materials. The way out, therefore, is for a close contact to be established between the technologists of both consumers and producers, even as the purchasing agent now has close commercial contact with the producers of his raw materials. Coordination of the two functions is had by man-to-man conferences and by means of a correctly worded specification.

It becomes clearer every day that this matter of steel specification is one for the specialist. His specifications should be held as simple as possible in order not to restrict unnecessarily the field of supply. Wherever possible the standard specifications of the Society of Automotive Engineers, the American Society for Testing Materials, and the National Specifications Board should be used. They have a very wide range and cover thousands of different materials. At times, special requirements may render such pro-

Relatively Few Grades of Carbon and Alloy Steels Are Sufficient for the Construction of Ice Machinery. Below is a photograph taken by Irving Browning of the CO_2 condenser in an air conditioner for a theater



cedure impossible, but in most shops this would be a rarity.

It should always be remembered that a tool or machine part should be just good enough for the job. It is poor engineering to build a strength into a part which the nature of its operation makes certain shall never be called upon. Acting on this principle, the following four points should guide the study of specifications:

1. What are the ideal qualities of a steel to do the job?

2. Is such a steel readily available on the open market?

3. What would the effect be of using an available but less ideal steel?

4. What methods shall be used to insure that the material received by the purchaser fulfills the specification?

If such an objective plan is not constantly in force, a swollen and unreasonable stock of steel is likely to accumulate. This is true even of those places where a sincere effort is made to buy only the best material for the purpose intended. If "buying the best" means buying the most suitable, and having someone in close relationship with the purchaser, continually checking up on this "most suitable" requirement, there can be little fault to be found. If buying the best means buying from the salesman with the most plausible story, or the most attractive promises, or the cleverest brand name, or the higher price, then the policy is merely a cloak for ignorance, and much of the material purchased, while intrinsically good, will not be particularly well suited for the purpose for which it was purchased.

Specialists on Materials

The above merely states facts discovered by hundreds of progressive organizations. It can be proven by the frequent appearance on the scene of men with such titles as Materials Engineer, Surveyor of Purchases, Engineer of Tests, Supervisor of Materials, Engineer of Materials—to mention only a few in a cursory scanning of the roster of one of our engineering societies. In a great many cases, also, the chief metallurgist (or whatever the man's title who has his eye on the way the metal fabricates and finishes) is in frequent consultation with the purchasing department, and his approval must be secured before any change is made or any new material specified.

It should be remembered that a good carbon steel, of proper carbon content and with only

manganese and silicon instead of additional alloying elements, can cover a vast field when correctly treated. When special circumstances require it, alloy steels can be resorted to. For the great majority of such applications a relatively small number will suffice. It is obvious that multiplication of grades and types will increase expense and chance of misapplication.

It should also be remembered that the advantages of an alloy steel over a carbon steel are insufficient to warrant the cost unless the importance of the part warrants the additional expense of heat treatment. Furthermore, the physical properties of untreated alloy steels are unreliable, depending as they do on the amount of work done in the rolling mill, the temperature of the last pass, and the rate of cooling.

A few words are in order to consider the significance of the usual physical tests.

Elastic limit is of great importance in dealing with steel, especially the mild carbon steels. It marks the practical or design limit of static strength for machine parts and structures. The true elastic limit is not readily determined and depends to a considerable extent on the accuracy and the sensitivity of the test equipment; for materials of structural grade it is generally but erroneously assumed to be identical with the "drop of the beam" in the tension test. Some cautions must therefore be borne in mind: A serious overload will change the elastic limit and the ductility of the mild steels, and therefore the useful life of the part. Tonnage steels of the structural grade in the as-rolled condition also have a quite variable elastic limit (in distinction with the figure derived from the drop of the beam). Steel in the hardened and drawn condition has an elastic limit fairly close to the ultimate strength, and in these steels the figure is valueless for design or appraisal purposes.

Tensile strength is frequently not of the direct importance that is sometimes supposed. In most instances the machine part will have failed before the full tensile strength is developed. The tensile strength does give a fair index of the resistance of the part to repeated stress or fatigue. It may be wondered why compression tests are so seldom made, but it must always be remembered that in a long structural member or machine part a compressive failure is caused by buckling or flexural action. Consequently the tensile stress set up in one side of the part will be the limiting factor of its strength.

Ductility — a property not easily measured — is, in the author's opinion, a most important attribute of a good steel. It prevents shattering collapse when the elastic limit is reached even at a tiny spot in the part, and will prevent the formation of minute cracks under occasional overload and eventual failure by extension of these flaws. Elongation and reduction of area in the tension test give the best measure of ductility. Strangely enough, the fatigue or endurance limit has no relation to the ductility. Endurance limits are determined in the laboratory on beautifully finished test pieces, and represent the maximum repeated stress which a steel is capable of withstanding indefinitely. Ductility, however, will permit the steel to yield in such a way that the occasional maximum stress does not repeat itself more than once at the same focus.

Hardness is the test most often made because it is the easiest and probably the most informative. It gives a reliable index of the tensile strength, and therefore of its endurance limit. However, it has its limitations. Wear resisting qualities of types of gear steels, for instance, cannot be compared by their respective hardness readings; neither will the hardness number give an index of the steel's machinability except to set a commercial limit for metal of the same chemical composition and similar history.

Machinability is likely to be the prime consideration for many small machine parts. The following table lists the machinability of some

S.A.E. Number	Type	Machinability
1112	Bessemer screw stock	100%
X1315	High manganese, high sulphur	85%
1120	Open-hearth screw stock	80%
X1350	High manganese, high sulphur	75%
6140 annealed	Chromium-vanadium	65%
4130 annealed	Chromium-molybdenum	65%
2330 annealed	Nickel	65%
1040	Machinery steel	60%
1035	Mild steel	60%
1020	Soft, open-hearth steel	60%
6120	Chromium-vanadium	60%
2345 annealed	Nickel	60%
3115	Nickel-chromium	55%
2315	Nickel	55%

common steels relative to bessemer screw stock as 100%. For parts which are finished all over the tendency would always be to select steels as near the top of this list as possible.

As remarked above, a few carbon steels and a still fewer alloy steels will serve for most pur-

poses in a plant manufacturing industrial machinery. (This, of course, is in addition to the tool steels and stainless steels.) A list of them and their principal physical properties in the heat treated (or as-used) condition will now be given, together with some remarks on their uses and substitutions which may be made as occasion demands.

Flange steel, such as furnished to A.S.T.M. specification for boiler and firebox steels A 70-33, will have 55,000 to 65,000 psi. (pounds per square inch) ultimate strength, 25,000 to 30,000 psi. yield point, and 25% elongation in 8 in. Its machinability is poor. It may be used for plate sprockets, rings and disks, and various irregular shapes not made in quantity but shaped with an oxy-acetylene cutting torch. It is also good for welding. There is a temptation sometimes to buy the cheapest possible grade of steel plate for these purposes. Such material containing much slag inclusions is unsuitable for gas cutting and the time and labor lost (not to mention the scrapped material) renders its purchase a false economy. With good flange quality plate the cutting can be done to limits leaving a minimum of machining necessary. The economy of fabrication more than pays for the better quality material.

What Is in That Steel?
Photographed in Chemical Laboratory of Allis Chalmers Mfg. Co.

S.A.E. 1112 and 1120 (screw machine stock) have excellent machinability and may be freely used for lightly stressed parts. Surface hardening in cyanide baths is a common operation, although for regular carburizing operations X1315 is much to be preferred.

An easy machining material is X1315. It contains 0.10 to 0.20% carbon, 1.25 to 1.55% manganese, and 0.08 to 0.13% sulphur. On account of its extra manganese it can be counted upon to develop 65,000 to 75,000 psi. tensile strength, 35,000 to 45,000 psi. yield point, 30 to 35% elongation in 2 in., and 50 to 60% reduction of area. It carburizes readily; in fact, similar penetration is had in 20% less time than required for open-hearth soft steel, and the case will be more uniform and the core tougher. It therefore is excellent for screw machine parts to be carburized, small forgings, bolts, levers, brackets, sprockets, pinions and rollers—in fact, nearly all parts where superior strength is not essential. The non-deforming characteristics contributed by the manganese make it especially valuable where it is desired to reduce the warping of the carburized part to a minimum.

S.A.E. 1020 (soft open-hearth steel) is not nearly as machinable as the above, X1315. If "normal" in microstructure, it is of good carburizing qualities. It is not quite as strong nor as ductile as the higher manganese analysis; in fact, its principal advantage is its ready availability in all sections and shapes and its low price—a matter which may be evanescent if parts are to have much machine work done on them. It is also excellent for welding.

A very great number and variety of machine parts are made from the medium carbon range of plain steels and, given proper thought, a still greater use could be made of them. By medium carbon is meant from 0.25 to 0.55%. Parts for which these steels are used always have definite physical requirements. The S.A.E. steels 1030 to 1045 have proven their value in this class. They respond readily to heat treatment; for instance, S.A.E. 1035 can be counted on for 70,000 to 80,000 psi. tensile strength, 40,000 to 50,000 psi. yield point, 18 to 28% elongation in 2 in., and 34 to 45% reduction of area. While machin-

ability (even when normalized to a coarse grain) is not particularly good, the material is excellent and widely used for parts requiring fair strength, such as forged crankshafts, crank pins, piston rods and heavy duty gears.

Medium manganese steels may be frequently substituted for the above if more severe service is to be met. Cost is but little increased, and they give better machining properties and response to heat treatment. The theory that running the manganese up would increase the brittleness beyond safety has been entirely discredited, and was, in fact, based on an often-quoted conclusion from some experiments on an alloy of entirely different microstructure. Steels classed as S.A.E. X1350 and X1360 have average carbon of 0.50 or 0.60% respectively and 0.90 to 1.20% manganese. Either is good for 90,000 to 110,000 psi. ultimate strength, 55,000 to 60,000 psi. yield point, 20 to 30% elongation in 2 in., and 35 to 45% reduction of area — really a superior combination.

The author's first choice of alloy steels for severe service requiring strength, toughness, resistance to wear and fatigue, is the chromium-vanadium steels, S.A.E. 6100 class. Their alloy content is moderate, and their first cost is therefore low. Their machinability is fair. The 1% chromium gives a deep, uniform hardness, while the 0.18% vanadium refines the grain and therefore toughens the alloy.

The importance of a carburized part such as gears, wrist pins, rotary shredders may require an alloy steel. S.A.E. 6120 when carburized and hardened develops a hard case and exceedingly tough core, the needed combination for shock and wear resistance. Another steel for similar service is the nickel-molybdenum steel S.A.E. 4615. Without a high temperature treatment it develops a hard case and a core of good ductility with the minimum distortion of the piece. For parts which are finish ground after treatment the S.A.E. steel 2320 may also be used to advantage, as it will be relatively free from surface checks after treatment.

The chrome-vanadium steel S.A.E. 6140 is a most useful general purpose alloy steel having the following physicals: Tensile strength 145,000 to 160,000 psi.; yield 120,000 to 135,000; elongation 15 to 20% in 2 in.; and reduction of area 40 to 50%. It is suitable for highly stressed machine parts, such as constant-mesh gears and worms, shafting, cams and cam rollers. In heat treated condition it is machinable, and parts of shape difficult to heat treat may thus be produced from the heat treated bar or block. Without developing extreme hardness this steel has a very high resistance to wear. It has a naturally dense, homogeneous structure which develops a work-hardened case in service without loss of dimension. This case gives a wear resisting quality equal to many file hard carburized parts.

The chrome-molybdenum steel S.A.E. 4130 is somewhat similar in its character to the chrome-vanadium and may often be substituted for it. For the same type of duty such steels in the nickel and nickel-chromium group as S.A.E. 2330 and 3130 have an important place.

The above notes by no means exhaust the subject. They make no aim to cover the highly specialized alloys used in automobile gears and transmissions, for instance, nor the high alloys used for heat or corrosion resistance. They are intended to indicate, however, that a remarkably small number of analyses will be amply sufficient for most applications in the manufacture of machinery and equipment, and to emphasize the thought that while one steel may be substituted for another it should be interpreted to mean that the careful engineer will not regard them as interchangeable, but that a satisfactory practice and usage built up on experience should not be changed lightly without cogent reasons that it will be better and cheaper in the end.

Hardness Tests — Brinell, Scleroscope, Rockwell, Monotron — Are Indispensable to Metallurgical Control

BOOKS WORTH READING

of a metallurgical nature

Sound Ingots

THE CASTING OF BRASS INGOTS, by R. Genders and G. L. Bailey. 190 pages, 6½x10 in., blue cloth binding. Published by British Non-Ferrous Metals Research Association, London.

A Review by D. K. CRAMPTON
Chase Brass & Copper Co., Waterbury, Conn.

FOR very many years the "art" of casting brass was surrounded by utmost secrecy and no little quackery. The old-time caster depended as much on luck as on knowledge and more on magic than method. Such degree of success as he did attain was as much in spite of his efforts as because of them. Even today many practical casters hold to a most amazing medley of fact and fiction concerning numerous details of the process.

Much progress has been made in the last two decades. Technological investigations have gradually differentiated between real facts and inaccurate and fanciful tradition. Even so, the results obtained have been largely empirical, and the explanations offered for various phenomena have been less accurate than the observations themselves.

We only now enter a stage of development that might properly be called scientific. The methods pursued by the present authors lead to a clear connection between cause and effect. The role played by each factor alone and in combination with others is accurately evaluated. The conclusions follow logically from the results of the various experiments.

The general description of the characteristics and defects of cast ingots, contained in this book, needs no lengthy comment. The man in the brass mill will easily recognize a host of old acquaintances (if, indeed, not friends!) in the text and illustrations. He will also realize that basically the procedure and problems are not different in America from those in England.

The liquid metal in the crucible or furnace was studied by Messrs. Genders and Bailey apart from problems incident to its transfer to the mold. The importance of small amounts of certain elements, particularly aluminum, silicon and phosphorus, on rate of oxidation and character of surface films, is well brought out. The pronounced effect of this liquid surface film on the behavior in pouring and in turn on the character of the solidified surface is demonstrated.

Solidification in the mold, with its problems of segregation, crystalline structure, shrinkage and gas cavities, has previously been described by these authors in other publications. However, the matter is here thoroughly reviewed and well presented. The marked effect of turbulence due to the penetration of the stream of metal has probably not been fully appreciated by most readers.

The effects of such variables as casting temperature, rate of rise in the mold, design of the

mold, and mold dressings are treated at considerable length. The fact that many of the findings stated in this book are in harmony with ideas held by others does not detract from their value. To have confirmation of such is pleasing.

Probably the considerable importance of the mold material itself in relation to soundness and good surface is surprising to many readers. But the evidence is strong and the conclusions sound. The effect of the mold design and material on rate of solidification and hence structure is dealt with at length. The advantages of water cooled copper molds for thicker cakes for hot rolling are well brought out, but are shown to be unimportant in thinner sections for cold rolling.

Finally, the mechanism of solidification using such special processes as the Durville, the Erical, or bottom pouring, is described in detail. The first named they find (as have others) to be especially suited to aluminum-bearing alloys.

The reviewer has seldom read a technical publication of such immediate value in practice, or a "practical" work written on a more logical foundation. The authors are to be highly commended. The book should be read at least once by every man supervising or in close connection with casting and rolling operations in a brass mill. In particular it is recommended to those on this side who so complacently assume that practice and results here are of necessity superior to those across.

Extra! Fourth Edition!

METALLURGY OF IRON AND STEEL, by Bradley Stoughton. 599 pages, 6x9 in., maroon cloth binding. McGraw-Hill Book Co., New York. Price $4.00.

IT IS a common experience in the teaching profession that there is no money in writing specialized textbooks. But when such a book on metallurgy passes 10,000 copies in its second edition and reaches its fourth revision at the age of 26 years, one must admit that here is a rare exception.

The reviewer is at a disadvantage also. He is disarmed, for no matter what his criticism may be, he is faced with an accomplished fact — here is a book which has satisfied and is satisfying thousands of engineering readers. Even though he may think it too narrow or too wide in scope, there is no question but that it has been complete enough for the average reader. Professor Stoughton confesses in his preface that four new chapters were written, but could not be included without an unjustifiable increase in bulk and price. It was a wise deletion to make, in the light of experience with the former editions.

Paging through the new edition, one sees numberless evidences of recent revisions: A paragraph is inserted on the Aston process for making wrought iron; a whole section summarizes the Pittsburgh studies on the physical chemistry of steel making; a 4-ton high frequency induction furnace is photographed; a diagram shows the roller-welding of steel tube — and so on indefinitely. A valuable appendix to each chapter gives references for further reading; each title is followed by a brief commentary indicating its scope and quality.

All in all, this is a notable revision of a notable textbook.

The present reviewer frequently sends up a little prayer that authors and publishers may do something about half-tone illustrations. Professor Stoughton writes the clearest prose; at one place he cautions instructors against expecting students to comprehend his text without supplementary explanations and a thoroughgoing review; the line drawings are clearly intelligible to engineers. Now if he had only extended these laudable practices and ideas to the pictures! Too many of the photographs have no focal point, and the thing they intend to illustrate is submerged in a mass of unimportant surroundings. Perhaps he thought, "What's the use of worrying much about photographs, for the publishers will reduce them all to a deadly leady hue." Which they did! — inexcusably, in view of their ability to print excellently from type and line drawings.

X-Rays in the Shop

INDUSTRIAL RADIOGRAPHY, by Ancel St. John and H. R. Isenberger. 232 pages, 6x9 in., bound in dark red buckram. John Wiley & Sons, New York. Price $3.50.

A Review by KENT R. VAN HORN
Aluminum Co. of America, Cleveland

A COMPLETE treatise on radiography (or the use of radiant energy for non-destructive testing) has been lacking until the appearance of this book. There are a few English but more German textbooks which describe the complex analysis of the internal structure of metals and alloys by X-ray diffraction. Frequently a short chapter is devoted to industrial radiography and

then the atomic structure or physics of X-rays is exhaustively presented.

During the past few years many metal fabricating plants have employed radiography as an inspection or development tool. Recently the American Institute of Mechanical Engineers' code for class 1 pressure vessels accepted welding as a fabrication method if accompanied by complete X-ray examination of welded areas. This has enormously expanded the number of installations and the technical articles on the different phases of radiography. The authors have tried to weld this scattered information with their fund of practical knowledge to produce a manuscript covering the history, apparatus, technique, cost, and industrial applications of radiography. The practical aspects are presented; no attempt is made to offer a scientific conception of the existing theories.

Their discussion of the technique for exposing and preparing radiographs is extremely helpful and would consume years of commercial experience to attain, although the somewhat specialized methods used in the St. John Laboratory seem to be favored. The quantitative appraisal of the sensitivity of the fluoroscopic and photographic methods of detection is enlightening. A section on X-ray apparatus and installations is not as comprehensive as other chapters of the book and is, unfortunately, restricted to types with which the authors have associated or perhaps preferred.

A large portion of the book is rightfully directed to the inspection of castings and forgings, small and large, and the recent welding activities. Such hints as the exposure of the scarfs on welds and the technique for examining steel tubing are valuable. A particularly entertaining section is that on the inspection of paintings, coal, golf balls, and bronzes.

The book is copiously illustrated with many radiographs and diagrams in a most commendable effort to help the reader actually see the cited applications. The printers should be complimented on the reproductions of the high contrast films. It is unfortunate that so much of the illustrative material may confuse one not intimately connected with radiographic interpretation, because of the continual intermingling of positive and negative prints. Messrs. St. John and Isenberger are of the opinion that readers should expect to see cavities or less dense material either as light areas on some or dark spots on other reproductions — that is to say, they should be able to interpret either positive or negative prints. However, this book seems to emphasize the necessity of standardizing on one or the other. The reviewer prefers the use of negative prints, which are, of course, comparable to the X-ray films (negatives), a practice which has gained considerable acceptance, particularly in Europe.

Many useful tables complete the versatility of this handbook, such as data concerning absorption coefficient limits, lead protection limits, lead equivalents of other materials, exposure charts and costs. The cost figures may be misleading because of the unusually short time allocated to the preparation, alignment and exposure of films. Short exposure times do not always predicate conditions of sufficient contrast and definition. In fact, information about sensitivity limits for various thicknesses of different metals might profitably have been included.

In conclusion, it may be said that this book on this new and important field of inspection is not only welcome to the X-ray technician but should be extremely valuable to the metal consumer or producer and to the engineer.

High Speed Steel

The Alloys of Iron and Tungsten, by J. L. Gregg. 511 pages, 6x9 in., blue cloth. Published for Engineering Foundation by McGraw-Hill Book Co., New York. Price $6.00.

THIS is the third of the monographs published by the Alloys of Iron Research and maintains the high quality set by its predecessors. It, also, is a critical review of the literature, some 1800 articles being located and two-thirds of them studied and abstracted — an enormous undertaking.

One feature of this volume is new, or at least much more in evidence than before. That is the frequent reference to private communications and the reproduction of extended memoranda from American experts on points which are not clearly or adequately described in existing literature. Such familiar names as Mathews, Emmons, Sykes, Cox, and Gill are met in this connection. Obviously, critical appraisals by technologists in industry are of the greatest value in locating errors of judgment or statement, and insure that the present volume is as accurate and complete as care can make it.

While paging through this book on iron-tungsten alloys, one is struck with the fact that tungsten steels (without sizable proportions of

another alloy) are but little used now-a-days. The once popular magnet steels are replaced with the cheaper chromium steels or the more efficient cobalt alloys; in the high carbon tungsten tool steels the trend is to decrease the tungsten content and "stabilize" the alloy with manganese or chromium. Possibly this is a result of price competition, but of all the tungsten tool steels about the only one now remaining is the 8 to 10% tool steel for hot work — a regrettable fact in view of the remarkable abrasion resisting qualities of steels of this sort and those containing even less tungsten.

High speed steel is the most important tungsten alloy. In it tungsten is truly indispensable, and improvements have consisted not in eliminating expensive tungsten but in adding other elements like vanadium and cobalt. About one-quarter of the book is devoted to a discussion of the manufacture, treatment and properties of high speed, and at least as many more pages contain data which refer to the high speed range of composition. This is as it should be. It will undoubtedly be the portion of the book which will attract the metallurgist in the consuming industries and will make him feel that the book is worth what it cost him, for nearly every machine shop uses high speed steel, and this book is indeed an unequaled summary of information on that subject.

True Talk

Steel Makers, by Harry Brearley. 156 pages, 5½x7½ in., dark blue cloth binding. Longmans, Green & Co., New York and Toronto. Price 5 shillings.

SINCE the present reviewer detests blurbs in the advertisements of current novels, he resists the temptation to become too enthusiastic about this little book. The reader may refer to Mr. Collitt's letter to Metal Progress on page 52 of last month's issue for as good a review as I am likely to write.

Steel Makers is a collection of chapters ("letters" Mr. Brearley calls them) about the manufacture of crucible steel, the steel itself, the men who make it, sell it, and study and lecture about it. It is a little gem, and like a story by Stevenson, can be reread at not too long an interval — especially by those who are a bit cocky about their store of technical or scientific information, and who have not yet lost all humor or sense of proportion.

Such things as the following anent theory and practice make it easy to read the book through in a single sitting: "To know the ingredients of a rice pudding and the appearance of a rice pudding when well made does not mean, dear reader, that you are able to make one." Or the following on progress in high speed tool steel manufacture: "The maker of tool steel is traditionally activated along two lines: He has a Nosey Parker curiosity about what his neighbors are doing, and he is apt to believe that the greatest good may be conferred on steel by adding the greatest number of ingredients."

Mr. Brearley should have gone on to say, of course, that such remarks apply exclusively to British metallurgists.

General Index

General Index to Transactions and Metal Progress. 261 pages, 6x9 in., blue cloth binding. American Society for Metals, Cleveland. Price $3.00. (Parts II and III published separately at $2.00.)

IN 1927 the American Society for Steel Treating printed a general index of *Transactions*, Vol. 1 to 10, inclusive. Consolidated with this was an index of the two volumes of the *Journal* of its predecessor, American Steel Treaters Society. This present volume contains that index as Part I, together with Part II, a similar index of Vol. 11 to 20 of *Transactions*, bringing the matter down to 1933. All this work has been done by a single man, Frank T. Sisco, editor of Alloys of Iron Research, in a way which makes available every important paragraph in more than 20,000 pages of technical literature, no matter what the title of the article may be. Cross-indexing has been thorough; every item is listed under at least two key words, and when the importance or the context justifies, under three or four.

Marjorie M. Rud, of the headquarters staff, is responsible for a similar index to Metal Progress, from its first issue down to Jan. 1, 1933; thus Part III is coterminous with Part II.

Anyone whose library contains a complete set of these publications of the American Society for Metals and its predecessors, has, with this index, available under his hand an unrivaled source of information on modern metallurgy, containing the answer to nine out of ten problems met in everyday work, or a suggestion leading to the answer.

By E. O. Mattocks
Industrial Engineer
American Gas Association
Testing Laboratory
Cleveland

A PRECISION COUPLE

for measuring gas temperatures

OF ALL the temperature measuring devices available to the modern investigator, the thermo-electric pyrometer is doubtless the most familiar to the metallurgist and oftenest used. About four base metal couples and one noble couple have been established as the result of years of research work by a large number of people. As seen by the accompanying tabulation, they cover the range encountered in all commercial heat treatment operations, being limited only in the extremely high temperature region of melting furnaces and the various combustion processes.

Couple	Useful Range	Most Favorable Atmosphere
Copper constantan	-350 to 500°F.	Non-corrosive
Iron constantan	-350 to 1700°F.	Reducing
Chromel alumel	0 to 2200°F.	Oxidizing
Chromel X-copel	0 to 1000°F.	Oxidizing
Platinum platinum-rhodium	600 to 2800°F.	Neutral

It is not the desire to discuss the underlying theory of thermo-electricity, the various devices used to indicate or register the temperatures, nor the precautions which must be taken to eliminate instrumental errors. These matters are so well taken care of in practice that the pyrometer user is inclined to forget several sources of error, which may be a considerable amount when gas atmospheres are being measured. It is to this phase of the question that we now turn attention.

The cause of such error is usually attributable to the variety of methods by which heat is delivered to the point being measured, for it is this flow of heat which determines the temperature attained as well as the temperature recorded. The various methods of heat transfer to and from the temperature indicating device (which in this instance is a hot junction of two dissimilar wires) and their relative importance must therefore be fairly well understood.

The three forms of heat transfer are (*a*) conduction, (*b*) convection and (*c*) radiation. It is assumed that the reader is acquainted with the fundamental laws governing these three, or can readily consult a textbook of physics. However, it must be realized that during the operation of a thermocouple in a gaseous medium the resulting temperature at the hot junction is produced by the combined action of all three forms of heat transfer, and the relative importance depends to a great extent upon the temperature of the gas.

To obtain the "true" temperature of a gas is an exceedingly difficult task. For example, if a thermocouple is inserted into a moving stream of hot gas, the gas immediately next to the wire will give up some of its heat to the colder metal by conduction and then be immediately replaced by hotter gas. This process, in which moving gases continually give up a

portion of their heat as they pass the object being heated, is known as convection. Further, if the walls within which the gas is flowing are hotter than the thermocouple, they will radiate additional heat to it. As a result of both convection and radiation, the hot junction will eventually reach an equilibrium temperature, which will usually (but erroneously) be considered the true temperature. Even if the proper corrections are applied and the thermometer is perfectly calibrated, the chances of obtaining the *true* temperature of the gas stream are slight.

Errors From Radiation

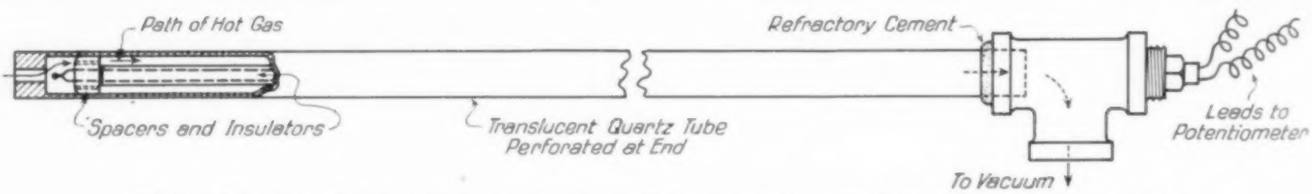
Let us examine again the flow of heat as the temperature of the pyrometer is coming to rest. It is obvious that only when the hot junction has reached the same temperature as the gas around it will a true reading be possible.

Now, if the wall temperature is higher than the gas temperature, as might be the case in an electric furnace, heat will be given from the walls to the thermocouple after the hot junction has reached the temperature of the gas, thus producing a high reading. On the other hand, if the walls are cooler than the gas, as in a chimney, heat will be radiated to the walls from the pyrometer faster than the gas stream can impart heat to it, thus producing a low reading.

Therefore, only in the very rare case when the wall temperature is exactly the same as the gas temperature will it be possible to obtain a true recording of temperature of the gas. Even then other conditions might tend to interfere, such as conduction of heat along the wires and the protection tube.

To overcome such errors caused by radiation, several possible courses are available. First, the walls may be well insulated so that they approach the gas in temperature. Second, the wall temperatures may be made the same as that of the gas by heating them with auxiliary heaters — this can be conveniently done only in small furnaces or flue pipes. Third, the thermocouple may be protected from energy radiated to or from the walls with a shield which has a high degree of reflectivity; in this case, however, it will be necessary to allow the gas to circulate freely around and through the device. Fourth, the thermocouple may be encased in a highly reflective protecting tube which is provided with a means of drawing the hot gases into the tube and over the hot junction.

The first two methods of overcoming the effect of cold walls (insulating and heating the wall) can be done relatively easily at low steady temperatures but can hardly be applied to very hot gases, especially in large furnaces. In the latter case the last two corrective methods (involving open protection shields and closed protecting tubes) are much more likely to be used successfully.

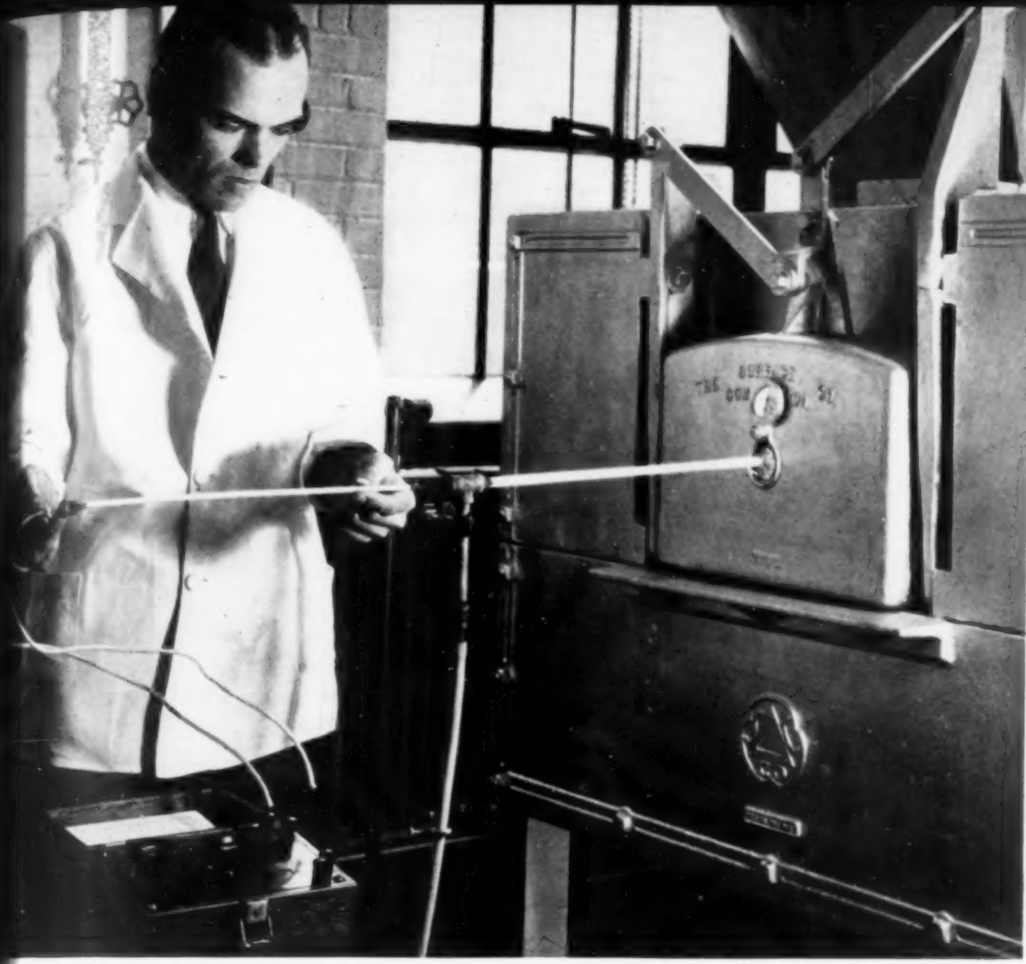


Sketch Showing Construction of American Gas Association High Velocity Thermocouple. Vacuum draws current of gas, whose temperature is desired, rapidly past hot junction

While determining the flue losses of furnaces employed in industrial research work conducted under the supervision of the committee on industrial gas research at the American Gas Association Testing Laboratory, it became apparent that true flue gas temperatures were not being obtained, although the thermocouples were being used in the ordinary manner. As a result of subsequent experimental work conducted in an effort to eliminate the errors, a thermocouple was developed which applies the fourth method given for obtaining true temperatures. This should be of interest to all who measure industrial temperatures.

High Velocity Thermocouple

The "American Gas Association High Velocity Thermocouple," as shown in the diagram and photograph, consists of a translucent quartz tube which is partly closed at one end, while the



Couple and Protection Tube About to Be Assembled Prior to Insertion Into Furnace

it will have little effect on the temperature of the gas stream entering the tube.

Third, the velocity past the thermocouple bead must be high enough to supply heat to the bead faster than the bead can radiate heat to the tube surrounding it.

Fourth, the tube surrounding the thermocouple bead should possess low absorption and high reflection factors. Translucent quartz meets these requirements as well as almost any material, especially at high temperatures, although at low temperatures thin tubes of polished copper might be better.

other end is connected to a vacuum line. Inside this quartz tube the thermocouple is so placed that the bead is located a short distance behind the small opening in the restricted end of the quartz tube, and centered by a porcelain spacer.

The entire assembly is inserted into the hot gas stream, locating the perforated end at the place where the temperature is desired. A period of time is then allowed to permit the quartz tube and thermocouple to come to equilibrium temperature. (For reasons to be shown later, this reading is generally recorded.) The vacuum is then turned on and a short time permitted to elapse before the temperature is again read.

The following conditions must be satisfied to obtain the true temperature of the gas: First, the time interval between applying the vacuum and taking the temperature reading must be long enough to permit the thermocouple bead to become thoroughly heated to the temperature of the flowing gas.

Second, the vacuum must be sufficient to create a relatively high gas velocity past the thermocouple bead, for there should be no temperature drop between the gas entering the quartz tube and that passing the thermocouple bead. In other words, the velocity should be such that once the restricted end of the quartz tube is heated to near the temperature of the gas stream,

From the previous discussion of the effects of radiation on recorded temperatures, it can be seen that the high velocity thermocouple will measure correct temperatures in a furnace whose walls are either hotter or colder than the gas. In order to insure accuracy, several preliminary steps should be taken, as follows:

To determine whether the attainable vacuum is sufficient to meet the requirements, the quantity of gases being drawn through the tube should be appreciably throttled and the indicated temperature noted. The quantity of hot gas should then be slightly increased and the temperature again noted. This operation should be continued until the vacuum is turned on full. If a maximum temperature is reached before the quantity of gas being drawn through the tube reaches a maximum, the vacuum is satisfactory.

Since it is possible for the thermocouple to be damaged during a reading, especially if the gas being drawn past attacks the wires, it is advisable to draw a check curve such as shown in the figure on page 40, plotted from readings taken both before and after the vacuum is applied, for several different equilibrium temperatures. However, all these readings must be taken with the assembly in the same location. By plotting the indicated ("no vacuum") temperature against the true ("vacuum") tempera-

ture, a straight line should result. If any pair of observations do not plot on this curve (such as A, B, or C), it is advisable to check the readings with a new bead or an entirely new thermocouple.

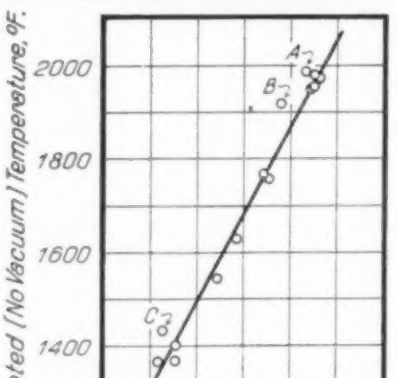
Incidentally, these curves show the effects of radiation upon temperatures as recorded in a particular set-up, even though the indicated ("no vacuum") temperatures are lower than they would have been if the thermocouple had not been confined inside a quartz tube.

Relative Temperatures Are Useful

Having considered the necessity of taking special precautions if true gas temperatures are to be obtained, it is natural to question the exactness of most temperatures recorded in industry. For example, consider a continuous carburizing furnace. Thermocouples extend from the roof of the furnace down between the rows of moving pots in some cases, and close to the tops of the pots in others. These thermocouples automatically control the quantity of air and gas that is burned in the furnace and maintain a practically constant temperature (or to write more precisely — a straight-line curve on the recording chart).

These thermocouples, however, do not record the true gas temperature, but a rather useful equilibrium temperature which is the resultant of the gas temperature, the pot temperature, and the temperature of furnace walls, top, and bottom. Although the hot gas heats both pots and thermocouples up to a point near its own temperature, the pots and thermocouples radiate some of their heat to the cooler furnace walls. Consequently, the temperature, as recorded, is not the gas temperature, but a temperature more nearly corresponding to that of the pots.

Nevertheless, it can be easily seen that a temperature more useful than the true temperature is being measured. This example emphasizes the fact that it is absolutely necessary to decide on the temperature desired before attempting to record any temperature measurements.



Temperature Observed by High Velocity Thermocouple Is Lower Before Vacuum Is Turned on Than After. If linear relationship is not maintained, as at observations A, B, and C, some source of error must be removed

A final point may be made about protecting tubes. By keeping hot furnace gases from coming in contact with the wire the strength and life of the thermocouple is increased. Where couples are used in detrimental atmosphere, tubes are a necessity.

It is essential that the tube be as good a heat conductor as possible in order to minimize the time lost between any change in furnace temperature and its influence on the encased couple. However, such a protecting tube may conduct heat outside of the furnace at such a rate that the temperature recorded by an unprotected thermocouple will never be reached. The greater the immersion of the thermocouple and its protecting tube in the furnace, the less will be this error due to conduction.

Still another error may be introduced by a protecting tube, although it may be negligible in magnitude: Since the protecting tube is considerably larger than the thermocouple bead, the amount of radiation received by the tube may be different from that which would be received by the bead alone. To test for the combined effect of these two errors, an unprotected thermocouple of the same length as the protected one may be inserted into the furnace for just enough time to allow the couple to reach equilibrium and a comparison reading taken.

In summary, it may be pointed out that either a bare or a protected thermocouple cannot register the true temperature of a hot furnace atmosphere except under a very rare combination of circumstances, as when radiation and conduction are close to zero. Consequently industrial control of temperature is at present based upon relative rather than true temperatures. This does not mean that the control is inefficient, merely that the temperature read at the chart does not correspond to the furnace temperature near the hot junction.

In the equipment described above, a stream of the hot gas is sucked past the hot junction of a thermocouple contained in a translucent quartz tube. Convection of heat brings both the tube and the thermocouple very close to the temperature of the flowing gas.

By Marjorie M. Rud
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WIND INSTRUMENTS

require various metals and alloys

WHILE stringed instruments (pianos, harps, violins) require strong, hard material which can be used in high tension, band instruments need a metal of anti-corrosive qualities which can be easily formed into a perfectly flared bell, which can be plated easily, has proper resonance, and is capable of producing a musical tone of clarity and intensity.

It is necessary for the manufacturer to be an expert in the spinning, machining, fitting, and soldering of small parts. A saxophone is a relatively simple instrument when compared with the French horn or Souza horn, yet it is made up of 548 parts, and its stem or body, only a few inches long, has 23 tone holes and 53 key posts.

Two types of brass are suitable for most wind instruments. Sheet brass for main bodies of horns contains about 75% copper and 25% zinc; it has a higher melting point than ordinary 65-35 brass, thus it does not soften when seams are brazed with a 50-50 alloy. Rods and tubing for levers and fittings are usually of free-turning brass containing 3.5% lead, 62% copper, and 34.5% zinc.

Other metals extensively used in building band instruments, as at the factory of H. N. White Co. of Cleveland, are nickel silver, bronze, and sterling silver. Spring steel is also needed for key and valve action. Silver and gold are used extensively for plating.

Nickel silver is used for flutes, piccolos, clarinets, and for parts of high precision in other instruments. Sterling silver gives a slightly better tonal quality than brass and is used for the bells of higher priced instruments.

Band Instruments

Clarinets, saxophones, trumpets, cornets, horns, and trombones are made in two main sections, body and bell. The body may be a simple one-piece tapered tube as in the clarinet, or it may be a complex aggregate such as the tuba or Souza horn, which has seven sections of curved conical tubing joined to form two complete circles, with additional lengths of straight tubing joined by elbow bends. For such body sections, sheets are cut to correct size and taper, bent into a tube, crimped together, and brazed. The seam is then flattened and smoothed by rolling and the tube itself is smoothed and straightened over a cone-shaped mandrel, by forcing over it a thick disk of lead having a hole cut in it just large enough to enter the small end of the taper.

Tapered sections of large horns are formed to the correct arc by bending around wooden or metal forms. To retain their shape during bending they are filled with a hard pitch which is afterward melted out. Lead was formerly used, but pitch is lighter and easier to handle. Bent tubing of uniform bore for trumpets, French

Blah! *Photo by Rittase*

horns, cornets, and trombones is formed in the same manner.

Small elbows are punched in two halves and brazed together. Large elbows and saxophone bells are cut and formed by hand from sheet and the seams brazed. This shape is then inserted into a steel die and a large ball of lead forced through. The ball flattens out as it passes through and forces the metal smoothly into the shape of the die. It is then ready to be brazed to the body.

Wide-mouthed bells, such as those for trumpets, horns, and clarinets, are brought to correct curvature and shape by spinning, after the crude form has been brazed to the body. Large bells are spun in six operations with an anneal after each step; small ones can be done in one step. A high degree of skill is required for this process, since the bell is the sound box of the instrument and must be perfect in shape and uniform in thickness. At the end of this operation a nickel silver wire is inserted in the outer rim of the bell to strengthen it against bumps and dents.

After polishing, buffing, and engraving, the instruments are ready for rough assembling. (Finish assembling is after the instruments are plated.) Rough assembly consists of drilling air passages or valve holes and setting up key posts. This is done on one machine into which the body is locked at keyways, cut into the mouthpiece-end when the tube was first formed. Valve holes and key post spots are then precisely located by templet. Narrow valve castings and key posts are then attached with silver solder.

Valves are of bronze or nickel silver and are rough ground at this stage. The final 0.001 in. for an air-tight fit is ground off by hand in the final assembly. The trombone slide is another delicate part. It must be a perfect fit and yet move easily without wear. The piston is made of nickel silver accurately ground to size, but the slide casing is usually of brass.

Before plating, the instruments are cleaned with lye and acid and scrubbed with pumice. Five types of surface finish commonly found on band instruments are as follows:

(*a*) Highly polished brass. Only 2% of the instruments now manufactured are left unplated. Most of these are bugles. Tarnish can be lessened by lacquering, but the lacquer soon wears through.

(*b*) Silver plate. The white color of the freshly deposited silver is given the correct luster by wire brushing.

(*c*) Silver with gold trim.

(*d*) Satin gold plate, produced by sand blasting before plating.

(*e*) Burnished gold plate, made by rubbing a quadruple plate with a flat steel instrument. This is the finest finish for brass instruments.

The standard finish (mostly used) on band instruments is what is known as a No. 2 finish. It is a heavy triple silver plate. The bell part of the instrument is lined with gold, and all relieved points such as rings and engraving are buffed to a bright finish.

Chromium plate has been tried by one manufacturer interviewed, but he found it too hard for the necessary finishing operations. It also tended to peel off. However, it would be a very satisfactory finish from the standpoint of wearing qualities and resistance to corrosion from perspiration and saliva.

In final assembly the keys, levers, and mouthpieces are attached. These are delicate operations since the height of the key determines the pitch, and the tension of the spring is important for rapid action. Each instrument is

painstakingly inspected and tested by an expert.

In addition to band instruments, many of the former woodwinds are now made of brass, nickel silver or sterling. The clarinet, oboe, and flute are examples of this type which have been developed in metal during the last few years. Size and length of air column and position of tone holes are important to volume and evenness of tone and these can be made more accurately in metal. Metals are also more resistant to climatic conditions, particularly dampness, than wood. Similar circumstances have warranted the construction of violin bodies of metal.

Organ Pipes

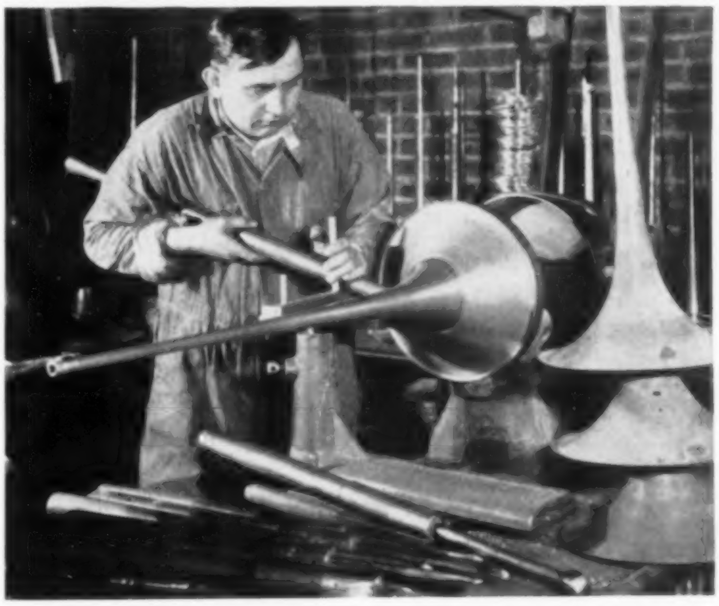
Manufacture of organ pipes represents a striking contrast to the modern machine methods employed for most musical instruments. Accuracy and quality are obtained not by machines of high precision but by the skill and artisanship of the individual worker. This industry harks back to the days of the craftsman, responsible for his product from beginning to end and possessing great skill and pride in his work. Attempts have been made to adopt modern mass production methods, but all have failed to produce an instrument equal esthetically to the organ with hand-made pipes.

Pipe manufacture in the plant of Votteler-Holtkamp-Sparling Organ Co. (a Cleveland firm specializing in church organs) varies little from the procedure of the eighteenth century. One man does all the work from the casting of the metal to the finishing of the pipe. Lead-tin alloys of three general classifications are used. These are "common metal," containing 20 to 30% tin; "spotted metal," about 45% tin; and "pure tin," 90 to 95% tin. The largest pipes, requiring greater strength and stiffness, are of pure zinc.

Organ metal scrap and pigs of tin and lead are melted in a simple gas-fired pot. The artisan weighs only approximately, but rather, like a good cook, relies upon long experience and skill for correct proportions. Sometimes a check is made by casting a standard-sized piece and comparing its weight with another known to be the correct alloy. The alloy is cast (by methods described below) in sheets on a long slate table covered with two thicknesses of heavy cloth drawn smooth by weights. One cloth will last for about 3000 lb. of metal, and each sheet weighs from 32 to 75 lb. This means about 60 casts.

The technique of this operation is interesting: A small casting ladle hung above one end of the table is filled by hand from the furnace. Cold metal of the same composition is then added to the ladle to cool the alloy and it is stirred until it commences to "grain." At this temperature one of the constituents (depending upon the composition) has started to solidify; the dross is skimmed off and the metal is ready for pouring into the casting box or "sled." The "sled" is a wooden frame 28 in. long and 8 in. wide with no bottom and with the back side adjusted to the correct distance from the table for the desired thickness of sheet. The sled is pulled down the table by two men, leaving the cloth tabletop covered with the metal sheet. An iron trough at the far end of the bench catches any excess metal. The sheet cools almost immediately and is then rolled up and set aside for a week to age.

The body of the pipe and its cone-shaped foot are cut separately, by hand, according to pattern. The pieces are then rolled by hand over a wooden mandrel and the seams soldered. The solder used contains approximately two parts of tin and one part of lead. Edges of the pipe are sized with a mixture of whiting and gum arabic; when this dries a very narrow strip of



Tools and Equipment Used for Spinning Bells for Brass Horns in H. N. White Co. Plant. The workman presses a long lever, ending in a blunt-nosed or flat tool, against the rapidly rotating shell and thus reduces its diameter as required

Screen, or Display Pipes, of Skinner Organ in St. Thomas Episcopal Church, New York. Most screens are purely decorative, the real organ being concealed in a nearby room or gallery. Many of these, however, are speaking pipes

the sizing is scraped off the outside of the edges to be joined. In this manner the solder is kept from adhering to any part of the pipe except at the seam.

Perfect roundness of the pipe is secured by beating it with a wooden bar on a wooden mandrel. The small end or "toe" of the pipe is coned or partially closed by pounding with a cup-shaped brass instrument. In some shops toes are formed by a spinning operation. An upper lip on the body and a lower lip on the foot are flattened by pressing over a form. The outer edge of the languid (a cross-piece between body and foot corresponding to the roof of the mouth) must have a certain angle for correct "speech," and is cut to a pattern. The languid is soldered to the foot and the body of the pipe soldered over it. Ears are small straight pieces soldered at the front of the pipe on either side of the lips.

Tone of the organ is determined by the diameter or "scale" of the pipe, material used, thickness of the wall, and size of the mouth. This opening is cut to different sizes for different stops, its width being some exact fraction of the circumference of the pipe, and its height a definite fraction of the width of the mouth. For example, an organ stop is said to have a two-ninth mouth cut up one-third. This means that the width of the mouth is two-ninths of the circumference of the pipe and the height of the opening is one-third the width. Proportional dividers are used to obtain these dimensions with accuracy.

After the mouth is cut, the pipe is then taken to the "voicer" who nicks teeth into the languid and lower lip and adjusts their positions by ear. Lips for the large zinc pipes are made of a lead-tin insert for ease of fabrication and voicing.

Organs may have from 200 to 35,000 pipes ranging from ½ in. to 64 ft. in height. They are of two types — flue pipes (described above) and reed pipes. Reed pipes produce tones similar to those of a trumpet; instead of the mouth and languid arrangement they have a brass-tipped reed or tongue which vibrates in an air stream against a small brass rod.

Large pipes for bass notes, which were formerly made almost always of wood, are now being replaced by metal because of better tonal qualities.

CORRESPONDENCE

and foreign letters

Induction Furnaces in Sheffield

LONDON, ENGLAND — Apropos the leading article on "Induction Furnaces Vs. Open Hearth" in the February issue, it may be of interest to American metallurgists to have some details of similar furnace installations which Electric Furnace Co., Ltd., has recently made.

During the last two years three new melting shops have been started in the Sheffield district. These were built "from the ground up" for high frequency furnace work. In addition a large number of installations have been made in existing steel works.

The aspect of the three first-mentioned shops is rather unusual. The furnaces are contained in recesses at the front edge of the platform, and have no superstructure for tilting mechanism, so the platform is perfectly clean, and clear of obstruction. This is an important consideration in the manufacture of alloy steels, and it also decreases any risk of electric shock while working the furnaces. A longitudinal trench between the furnace platform and the general shop floor contains a track for ingot molds or ladle car. The motor-generator sets are situated in a special building about 100 ft. away, where the general conditions are similar to those of a modern power station, and all air is filtered before entering the building. The machinery is operated by a remote control panel near the furnaces, and the condenser bank is under the floor.

New qualities of steel and new standards of purity are obtainable with such equipment, and the saving in electrodes, refractories, and labor gives a melting cost far below that of arc furnaces, provided the production unit is of reasonable size.

The idea that the use of the Ajax-Northrup high frequency furnace is limited to small quantities of very high priced steel is a fallacy, as five-ton units produce steel of the highest quality with the accuracy of a laboratory experiment on a reasonable production basis.

The results of five consecutive heats of valve steels made in a 650-kw. furnace recently installed near Sheffield are shown in the table.

Data From Five Consecutive Heats

Heat No.	Total Time Min.	Interval Between Heats	Power Consumption Kw-hr. per ton
27	104		530
		7	
28	101		522
		5	
29	103		516
		5	
30	108		536
		6	
31	106		522
Average	104	6	525

Power consumption includes all losses in the electrical machinery. The low figure of 6 min. interval between heats (for casting, cleaning the furnace, and charging) is obtained by the improved tilting apparatus and methods of charg-

ing which we now incorporate in this type of equipment.

The high frequency furnace has already produced new metals to improve our radio transformers and magnets. New standards of purity in nickel-iron alloys have been attained, which have increased seven-fold the speed of submarine telegraphy. New highly alloyed tool steels, and many steels containing aluminum have been introduced, but these advances seem to be only a beginning of what this new furnace should produce in the hands of the skilled steel maker.

D. F. Campbell

Clean Steel Should Be Sounder Than Dirty Steel

Turin, Italy — May I be permitted to comment upon recent letters, published in Metal Progress, concerning the important problem of internal defects in large forgings? Messrs. Houdremont, Margerum and Benter believe that a misunderstanding arises because the word "flakes" has not been clearly defined, but in my opinion the misunderstanding depends more on *facts* than on their interpretation.

The facts stated in my February letter to Metal Progress were obviously limited strictly to my personal (though rather extensive) practice in the manufacture of gun forgings. After reading the very interesting and authoritative discussion from three eminent metallurgists, I have to admit that my never having found flakes in gun forgings *made of really clean steel* (but only in steels whose purity was not completely satisfactory) has been very peculiar; and, I may add, very lucky for me!

But the facts I have stated have been confirmed, without exception, by official tests (records of which still exist) on tens of thousands of tons of forgings; and, what is a still better confirmation, by the fact that not a single failure due to flakes has ever occurred in the guns made with those *clean steel* forgings — neither during or after the tests of finished guns, nor in actual war service.

Therefore, it would be difficult for me to ascribe those facts to a mere coincidence.

On the other hand, I notice the following sentences in Mr. Margerum's letter:

(*a*) ". . . . flakes were not a serious problem in acid open-hearth gun steel melted in the plants of those firms with long experience in ordnance manufacture."

(*b*) ". . . . gun forgings of superior quality, made from basic electric steel, had been produced regularly in at least one plant before flake-producing practice was introduced."

These statements should prove, at least, that clean steel can be *normally* free from flakes, and that this fact has been ascertained by other steel works. These circumstances further confirm the reality of the facts I have just stated.

Taking into consideration only the facts I have constantly observed in my practice and confirmed by the practice of other important steel works, many of which I could quote, it seems to me that one is necessarily led to the conclusion that the impurities contained in steel must greatly increase the tendency to the formation of flakes. However, the discussion published in Metal Progress seems to confirm Ashdown's statement made in your issue of November, 1933, p. 15, that in many plants ". . . . the steels *most susceptible* (i.e., to flake production) are the *cleanest and most carefully made*, and those *more immune* are the *dirty* steels which on that account show very unsatisfactory transverse physical properties." (Italics are mine.)

It is, therefore, evident that the differences of opinions on the problem of flakes do not depend on different interpretations of the same facts, but are due to great fundamental differences in the facts themselves, as they have been observed in different plants. No wonder that different facts lead to different explanations!

While on other major points I quite agree with Mr. Ashdown's opinions, as I have already stated in my February letter, I am still of the opinion that some of the explanations offered by Mr. Ashdown are inconsistent with the facts I have constantly observed in my own practice.

It remains to discover the reasons for the fundamental differences *of facts* observed in different plants. This, for many obvious reasons, does not seem an easy problem. Perhaps a way toward the solution could be found in the suggestion of Dr. Houdremont and Mr. Margerum: That the facts observed in different plants should be better defined and more completely described. It is my opinion that — in addition to a better description of the defects that are to be considered as real flakes — it would be useful to define exactly "clean" and "unclean" steels.

Before closing this already too-long letter, I wish to call attention to the following points:

The admitted fact that flakes develop especially along the joints or contacts between the primary crystals, is evidently owing to an inferiority of the physical properties of the metal

along these joints. Now, an increased quantity of impurities increases the inferiority of the physical properties of the metal precisely along the joints where such impurities accumulate. Therefore, it does not seem easy to explain how the impurities could have no influence on flakes, and it seems still more difficult to explain how — according to Mr. Ashdown's statement — they could hinder or prevent the formation of flakes.

In other words, if the impurities contained in steel do not promote or favor the formation of flakes, it will obviously be necessary to hold to one of the following three positions:

1. To deny the fact (admitted by all metallurgists, including Mr. Margerum and Mr. Ashdown) that flakes are developed especially along the joints of primary crystallites where a concentration of impurities always takes place.

2. To admit that a concentration of impurities in a given region of a steel does not impair the metal's physical properties in that region.

3. To deny that impurities tend to accumulate along the joints of primary crystals.

I do not see any other possible hypothesis consistent with the statement that impurities do not favor the formation of flakes, and none of the above three seems to me to be tenable.

FEDERICO GIOLITTI

French Prefer the Term "Special Steel"

PARIS, FRANCE — If we admit that steel should be characterized by its elementary composition, the definition of alloy steel becomes extremely difficult, for the percentage limits must then be determined for the sundry elements at which the properties are modified as compared to those of ordinary steels.

But the problem seems to be more complicated still, at least in France, where the term special steel is in use. Special steels (*aciers speciaux*) have not been sold and characterized by analysis, but by trade mark and the mechanical properties that may be obtained after a definite treatment. It is believed that proper physical tests give security as to the mechanical properties, and that the trade mark is a guarantee as to uniformity, cleanliness, and utility — in short, for the quality of the steel.

The intentional presence of alloying elements in a definite and sufficient quantity is not regarded by French metallurgists as the distinctive characteristic of special steels, since blister steels and carbon tool steels are classed as special steels even though they contain no excessive quantity of usual elements (C, Mn, Si, S, or P).

The mechanical properties and the quality of steel (which distinguish the special steels on the French market) are, in fact, obtained by heat treatment and the following factors:

1. Intentional addition of definite elements supposed to have a favorable action, either special elements such as nickel, chromium, tungsten, molybdenum, or vanadium, or the usual elements, carbon, manganese, silicon, in quantities exceeding those in ordinary steels.

2. Contrariwise, the elimination or limitation of elements or compounds believed to be deleterious, such as sulphur, phosphorus, oxygen, or nitrogen. Such a refinement may be made by choice of pure raw materials and by the steel melting procedure.

3. Manufacture of products as compact as possible, free from physical and local defects, such as pipe, segregation, flake, cracks, as by topping the ingot and by examining and cleaning the surface.

4. Uniformity of fabrication, which is obtained by manufacturing under close control.

These last three factors (purity, soundness, uniformity) are the characteristics of fine steels or quality steels; the special steels belong to the same category and often contain elements especially added to modify the properties.

From the standpoint of French practice it therefore seems necessary to introduce the following distinctions:

1. Alloy steels (*aciers alliés*), or steels containing special elements. This distinguishes them from carbon steels.

2. Quality steels or fine steels, with a view to distinguish them from ordinary steels.

Thus we might obtain (*a*) alloy steels (which would be both a quality steel and an alloy steel), (*b*) quality carbon steels, and (*c*) ordinary steels, which might be plain carbon steels or which might even contain alloying elements.

For such a double distinction it is naturally indispensable to have some arbitrary limits to separate these categories, for the special elements called alloys may accidentally exist in every steel in comparable amounts to those in certain complex steels where they were intentionally added. Such is the case for nickel, molybdenum, tungsten, copper, or manganese. These elements may come from contaminated furnace linings or from scrap metal. Also, it would be impossible to mark with precision the moment when a steel becomes an alloy steel because of its silicon and manganese content.

Likewise the limiting percentages of impurities like sulphur and phosphorus are equally arbitrary ones. It would also be impossible, just now, to fix a limit for other impurities such as oxygen, nitrogen, and their compounds.

For this purpose the following conventions might be adopted: Alloy steels (or steels with special elements) might contain more than 1.0% of manganese or silicon; more than 0.5% of nickel or tungsten; more than 0.25% of chromium, copper, molybdenum, or aluminum; and more than 0.12% of vanadium.

Quality steels would limit sulphur and phosphorus to 0.03% maximum, to distinguish them from ordinary steels.

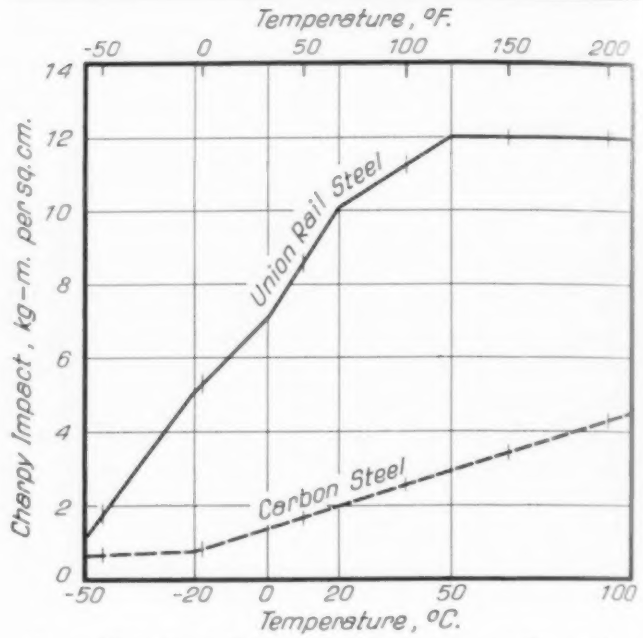
Such discrimination corresponds as well as possible to the existing conventions and customs of France.

ALBERT PORTEVIN

A Low Alloy Rail for Arctic Railroads

DORTMUND, GERMANY — Last December METAL PROGRESS printed a letter from Mr. Suslov on "Rail Failures in Siberian Winters," wherein it is stated that the Tomsk Railroad, during severe winter weather with temperatures down to —50° F., experienced frequent rail failures on account of brittleness. He then quotes a recent German investigation by Röttscher and Fink on the influence of temperature upon the notch toughness of low carbon steel, from which it follows that steels have been developed which have a satisfactory impact strength even at low temperatures. Special mention is made of the chromium-copper open-hearth steel, known as "Union structural steel" and developed in our laboratory at Vereinigte Stahlwerke, which when tested under the severest conditions still possesses a high notch toughness at low temperatures.

Mr. Suslov's conclusion, however, that rails made in the basic bessemer converter are inferior on account of their low impact strength at low temperatures cannot be accepted. First, it will be found that carbon steels made by other processes become as brittle, at those low temperatures, as basic bessemer steel. Furthermore, the Vereinigte Stahlwerke A.G. (proceeding from experience gained in the manufacture of the above-mentioned chromium-copper open-hearth steel) has succeeded in developing a new, tough rail steel, which is manufactured in the basic bessemer converter. This new "Union rail steel" is a low alloy steel and is distinguished by an extremely high tensile strength and toughness especially at low temperatures. It is characterized by a very low carbon content — less than 0.2% — and its needed physical properties and wear resistance are effected by small additions of relatively cheap alloying elements. The tensile strength is about 88,000 psi. and therefore somewhat lower than in the usual carbon rail steel, but it has a very high yield point (60,000 psi.) and an elongation of about 20% on 10 diameters. As shown on the accompanying diagram, it has an impact strength three or four times higher than the plain carbon rail steel, and retains this advantage at low temperatures. The curves represent the mean values of numerous tests. Especially remarkable and of great practical importance is its superiority below 70° F. (temperate atmosphere).



Low Alloy Steel Has Far Superior Impact Strength at All Temperatures to High Carbon Steel Rail

The danger of rail fractures, therefore, during the winter season, especially in a cold climate like Siberia's, may be regarded as practically eliminated. Furthermore, the high notch toughness of "Union rail steel" is of advantage in the drop test for inspecting rail steel. Thus, when struck with a 1000-kg. weight falling from different elevations upon rail sections about 4 ft. long, this low alloy rail not only fulfills the specifications of any country, but exceeds them 100%.

Three winters ago the German State Railway laid sample rails at several places where severe conditions exist; the rails have stood the test of service excellently in every regard.

E. H. SCHULZ

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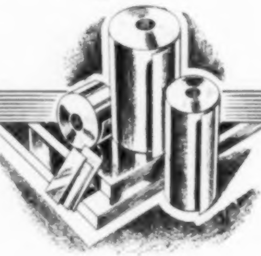

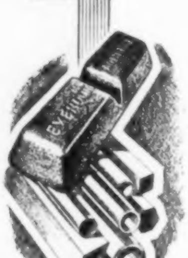

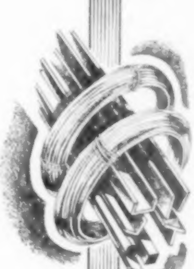

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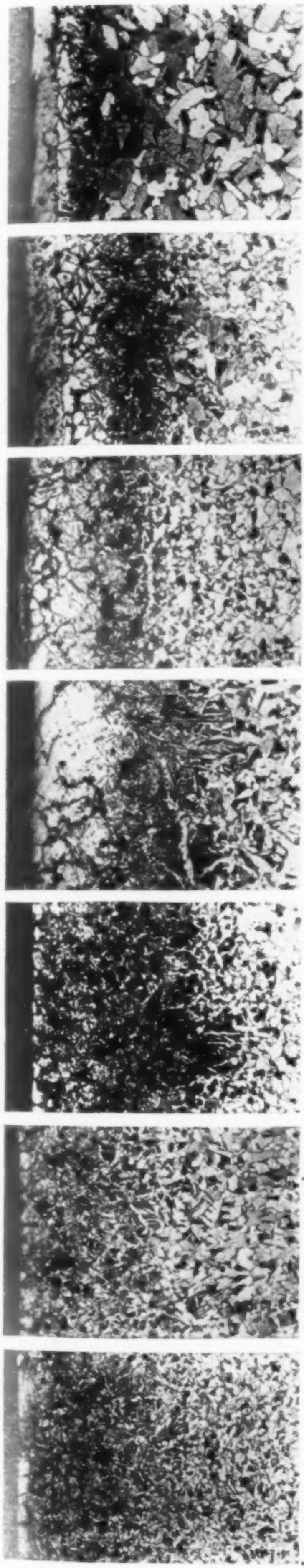

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